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# CANOTIA



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**Canotia** publishes botanical and mycological papers related to Arizona. These may include contributions to the Vascular Plants of Arizona project, checklists, local floras, new records for Arizona and ecological studies. All manuscripts are peer-reviewed by specialists. Acceptance for publication will be at the discretion of the editor. At least 30 printed copies of each issue are distributed to libraries in the United States, Europe, and Latin America. Anyone may download copies free of charge at http://www.canotia.org.

**Canotia** is named for *Canotia holacantha* Torr. (Celastraceae), a spiny shrub or small tree nearly endemic to Arizona. Cover illustration by Alandon Joe.


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## INDEX TO FAMILIES OF THE VASCULAR PLANTS OF ARIZONA

Published treatments (**in bold**) can be found in volumes 26, 27, 29, 30, 32, 33, and 35 of the *Journal of the Arizona-Nevada Academy of Science* (**JANAS**) or in subsequent volumes (1–15) of **CANOTIA**. Unbolded entries indicate families with no treatments published to date. Figure numbers refer to illustrations in the “Key to Families of Vascular Plants in Arizona” in **JANAS** 35(2). All Vascular Plants of Arizona treatments are available as pdf files online at (http://www.canotia.org/vpa_project.html).

**Acanthaceae CANOTIA 12:22-54. 2016. (T. Daniel)**
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**Sapindaceae JANAS 32(1):76. 1999. (A. Salywon)**
**Sapotaceae JANAS 26(1):34. 1992. (L. R. Landrum)**
**Saururaceae JANAS 32(1):83. 1999. (C. T. Mason, Jr.)**
**Saxifragaceae JANAS 26(1):36. 1992. (P. Elvander; Fig. 16)**
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**Simmondsiaceae JANAS 29(1):63. 1995. (J. Rebman)**
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**Solanaceae Part Three: *Lycium*. CANOTIA 5(1):17. 2009. (F. Chiang and L. R. Landrum)**
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**Solanaceae Part Five: *Chamaesaracha*. CANOTIA 9:13. 2013. (E. Manton)**
**Solanaceae Part Six: Nicotiana. CANOTIA 14:54. 2018. (E. Makings and J. P.Solves)**
**Solanaceae Part Seven: *Browallia*, *Calibrachoa*, *Capsicum*, *Jaltomata* and *Salpichroa.* CANOTIA 17: 46. 2021. (C. M. Currier, E. Makings, J. Anderson, J. Maranville, and Kariah Slagel)**
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Tiliaceae
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**Ulmaceae JANAS 35(2):170. 2003. (J. W. Brasher)**
**Urticaceae JANAS 26(1):42. 1992. (D. Boufford)**
Valerianaceae
Verbenaceae
**Violaceae. JANAS 33(1):73. 2001. (R. J. Little; Fig. 17)**
**Viscaceae JANAS 27(2):241. 1994. (F.G. Hawksworth and D. Wiens)**
Vitaceae
**Zannichelliaceae CANOTIA 14:63. (J. Ricketson)**
Zygophyllaceae (Fig. 17)

# Making Checklists with the SEINet Database/Symbiota Portals

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**ABSTRACT:** The Southwest Environmental Information Network (SEINet) is a consortium of herbaria from the United States, Canada, and Mexico that collectively provide a database of digitized specimens worldwide in scope but principally from North America. The SEINet Portal Network is one of many natural history collection databases that uses Symbiota software. Symbiota provides useful tools to generate searches based on geographic region, family, collector, year of collection, and more. These tools are readily available to the public, and our aim is to provide the knowledge to maximize their use, most specifically using the SEINet database. We mainly consider geographic checklists, lists of taxa found within a specific region. We also provide an example of a checklist based on a collector. Checklists serve many purposes including but not limited to, aiding in identification, indicating an area's documentation rate, illustrating the relative biodiversity of a region, or exploring the activities of a collector. We discuss multiple methods for creating checklists, including both temporary and saved checklists, and provide detailed examples from searches generated in the SEINet Portal Network to give a thorough overview of the checklist features available on portals that use Symbiota software.

## INTRODUCTION

The SEINet Portal Network, or the Southwest Environmental Information Network, was established in 1999 through a National Science Foundation grant (BDI 9983132) to the Global Institute of Sustainability at Arizona State University (ASU). One aspect of the original funded project was a database of herbarium specimens and that has become the main lasting contribution. Two later grants to ASU and collaborating institutions in Arizona (University of Arizona [ARIZ], Northern Arizona University [NAU], and the Desert Botanical Garden [DES]) provided funds for databasing and photographing specimens. Many other institutions joined the SEINet Portal Network with funding from Advancing Digitization of Biological Collections (ADBC, https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503559) or even with no funding. We were optimistic that the SEINet Portal Network would contain about 1.4 million records by 2013. It was nearly restricted to Arizona and adjacent states until then, but because the software used by the SEINet database, Symbiota (Gries et al. 2014), was so attractive and user-friendly, and because specimens from other parts of the United States could conveniently be added to SEINet, the database grew rapidly. As of 2021, SEINet includes nearly 15.4 million specimen records and over 260,000 observations from about 360 contributing institutions in North America. There are several Symbiota-based web portals, e.g., SERNEC, Consortium of Midwestern Herbaria, Intermountain Regional Herbaria

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Network, that provide front-end access to these data (http://symbiota.org/docs/seinet/), and the database continues to grow!

The purpose of this paper is to show how one can use Symbiota-based portals to make checklists. We first discuss making temporary checklists that might be used briefly, perhaps just as a quick specimen search. Later, we discuss saved checklists that are stored on Symbiota-based portals, available to modify and use for years. Our examples use the SEINet database and portals to that database, but all Symbiota portals work in a similar way, regardless of the database used. Thus, this paper may be useful to those using other Symbiota portals and databases. The availability of certain features, such as interactive keys, may vary depending on the portal being used.

A checklist is generally a list of taxa found within a specific geographic area. Checklists can provide information about how well-documented an area is by collections, the relative biodiversity of a region, and can aid in identifying new specimens. These geographically based checklists are discussed first. Similar lists of taxa may be made, unrelated to or only partially related to geography, for instance based on a particular collector, corresponding to a time-period, or as a study aid for a class. An example of this kind of checklist, based on a collector, is discussed last.

Many aspects of this paper are explained through videos on Symbiota YouTube Channel (https://www.youtube.com/channel/UC7glMVLRnTA6ES3VTsci7iQ); we encourage readers to also consult these. Individual videos of this series are cited in Resources and Literature cited.

## MAKING TEMPORARY CHECKLISTS WITH THE SEINET DATABASE

To make a checklist in a Symbiota portal, first, open one of the portals that provide access to the database. There are two kinds of homepages as of March 2021. Type A has link-choices (buttons) at the top of the page in a grey bar, for example, SEINet Arizona-New Mexico (AZ-NM) Chapter (http://swbiodiversity.org/seinet/). Type B has link-choices (buttons) along the left side in a list, for example the Intermountain Region Herbarium Network (https://intermountainbiota.org/portal/). Type A and B homepages work essentially the same and checklist data is shared across these platforms (Fig. 1).

For these examples we use the AZ-NM Chapter portal with the type A format. Locate the grey search bar at the top of the page. Hover over "Specimen Search" until a drop-down menu appears. Select "Search Collections" [for type B format, go directly to "Search Collections" in the left column]. The next page displays the list of herbaria that are available to search via this portal (Fig. 2). Typically, you want to search all the herbaria, but if you have a specific herbarium from which you would prefer to create a checklist, click "Select/Deselect All" to deselect all herbaria and then manually select the specific herbarium (or herbaria) to query. Next, proceed to the "Search" button on the top right-hand side of the screen.

There are four ways to create geographically based checklists in Symbiota websites. See Table 1, Fig. 3, and discussion below. As an example, we begin by conducting a locality search based on search terms.

Choosing the defining features of the location (e.g., state and locality) is the first step in a locality search. Generally, limiting the search to fewer terms such as state and one other feature facilitates a more inclusive search. On the other hand, it is best to be cognizant of using a place name that may be used multiple times in a state (e.g., "Sycamore Canyon" in Arizona). Sometimes an area is known by more than one name, for instance Pima Canyon and Guadalupe

Canyon are the same place, a locality in South Mountain Park of Phoenix, Arizona. In this instance, using a broad search term such as "South Mountain" in Arizona may help capture both Pima and Guadalupe Canyon. For this checklist example, we defined our search with "State: Arizona" and "Locality: Cabeza Prieta," which should limit the search to the Cabeza Prieta National Wildlife Refuge in southwestern Arizona.

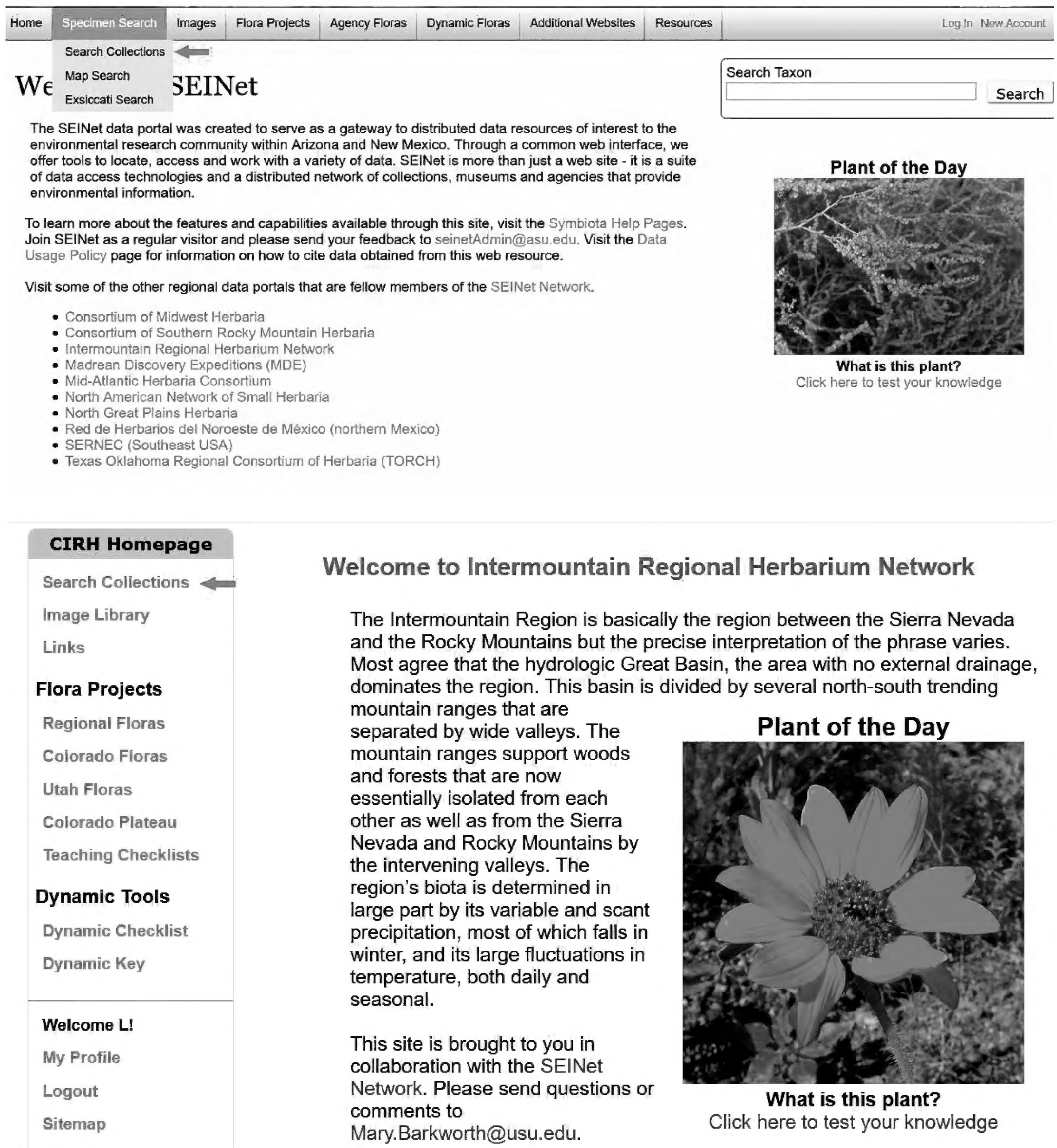



**Figure 1.** Examples of the two types of homepages. Type A (*Top image*) SEINet AZ-NM Chapter link-choices are located in the top grey toolbar. Type B (*Bottom image)* Intermountain Regional Herbarium Network link-choices are located in the left column. Arrows indicate button used to make a specimen search.

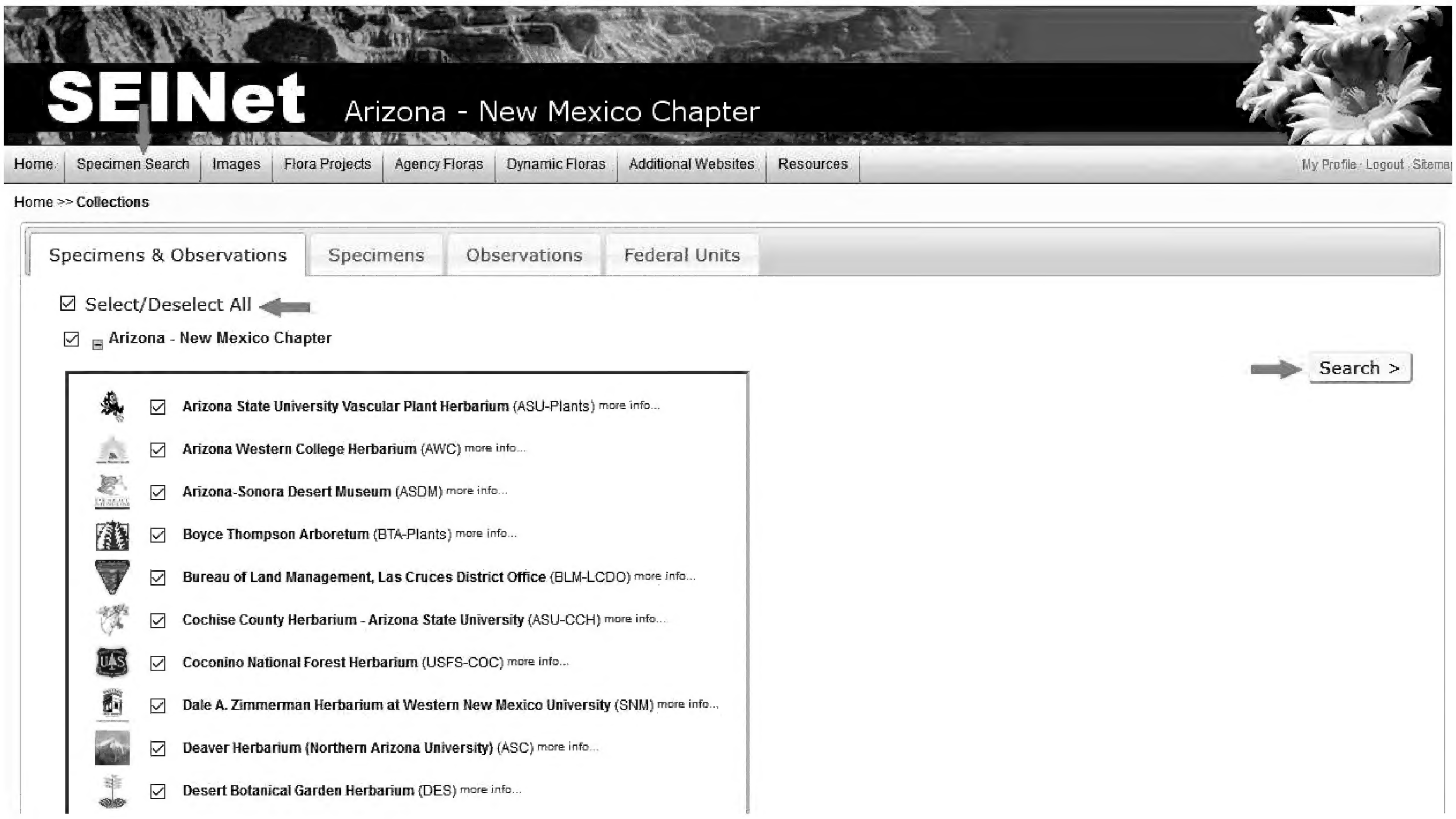



**Figure 2.** Web page format for initiating a checklist search. The three arrows denote how to begin the query by selecting from the Specimen Search dropdown menu on the top toolbar, Select/Deselect All for the list of herbaria, and the Search button to proceed.

**Table 1**. The four ways of searching for specimens to create geographically based checklists with Symbiota.

| | |
|---|---|
| ***Locality criteria*** | Search by using words for specific areas, i.e., country, state/province, county, locality, or elevation. This type of search is helpful for specimens that are not georeferenced, or if you are trying to make a checklist for a defined area such as the state of Arizona or Maricopa County. |
| ***Bounding box*** | Create a square/rectangle over a certain area. This type of search is useful for a broad search of a region, but it will exclude specimens that are not georeferenced. |
| ***Polygon*** | Create a custom irregular polygon shape. This type of search is useful for tracing boundaries of parks, preserves, forests, or other natural features that are not easily captured through a box or circle, but it will exclude specimens that are not georeferenced. |
| ***Point-radius*** | Create a circle in a certain area. This type of search is useful for searching from a certain point and expanding a uniform radius (e.g., 10 km) around the point, but it will exclude specimens that are not georeferenced. |

The next step is to display the results from your search and filter them appropriately. You will see two options on the top right-hand corner of the screen: "List Display" and "Table Display" (Fig. 3). For a comparison of these two displays see Table 2.

The List Display is generally better for making checklists and this discussion will proceed with that option. By selecting List Display a new page will open with three tabs, defaulting to the "Occurrence Records" tab. The Occurrence Records tab provides label information about every specimen. There are three buttons within this tab that allow you to 1) change output to table display, 2) download data of all specimens as a CSV file, or 3) copy the URL address for the search results (Fig. 4). The Maps tab allows one to make Distribution maps for all the georeferenced specimens and can often be informative, especially as a way to find poorly georeferenced specimens or problems with the search terms used. For instance, if

you had searched for "Sycamore Canyon" in Arizona it would be evident on the map that you had specimens from various localities. The Species List tab is the best for constructing checklists. Thus, we suggest that you switch to that tab (Fig. 4).

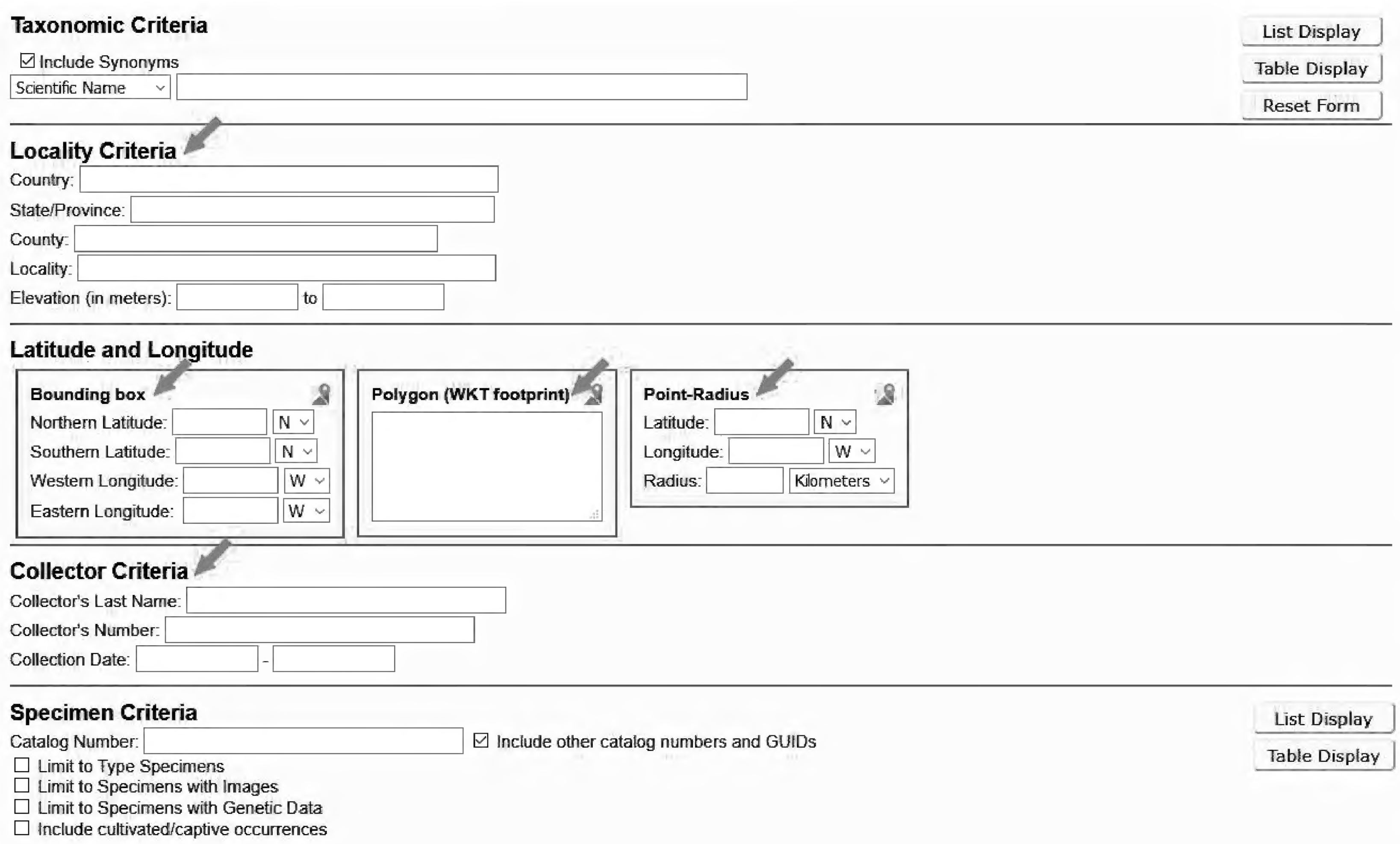



**Figure 3.** Search Criteria page for a specimen search. The five arrows point to the most common ways of searching for specimens to make a checklist. Locality Criteria (geography word search). Latitude and Longitude options (geography search using coordinates; all allow using a map by clicking on icon in upper right corner): Bounding Box (rectangle), Polygon (irregular shape), and Point-Radius (circle). Collector Criteria (searches based on collector, number, and/or date). Criteria can be combined from different sections, e.g., elevation from Locality Criteria with Point Radius map option. Searches can also be restricted by Taxonomic Criteria or Specimen Criteria.

**Table 2**. Comparison of List Display versus Table Display.

| | |
|---|---|
| **List Display** | Defaults to the "Occurrence Records" tab, which displays all observations and specimens alphabetically by herbarium. For example, Arizona State University herbarium might be the first herbarium listed. Switch to the "Species Tab" on the left for all the Taxa recorded in an area both through observations and specimens. The "Species List" tab list is alphabetized by family and scientific name within families. Each specimen is hyperlinked to a page in the Symbiota website that provides more information about, and images of, most organisms. List display, specifically the "Species List" tab, is the recommended option for viewing a checklist as it appears in a more user-friendly format. |
| **Table Display** | Lists all the specimens of all Taxa recorded in an area as a spreadsheet that can be sorted by up to two fields (e.g., collection, family, scientific name, etc.). This is not the recommended option for viewing a checklist unless you intend to download the data as a CSV file. One advantage of the Table display is that it allows one to see the relative abundance of taxa. |

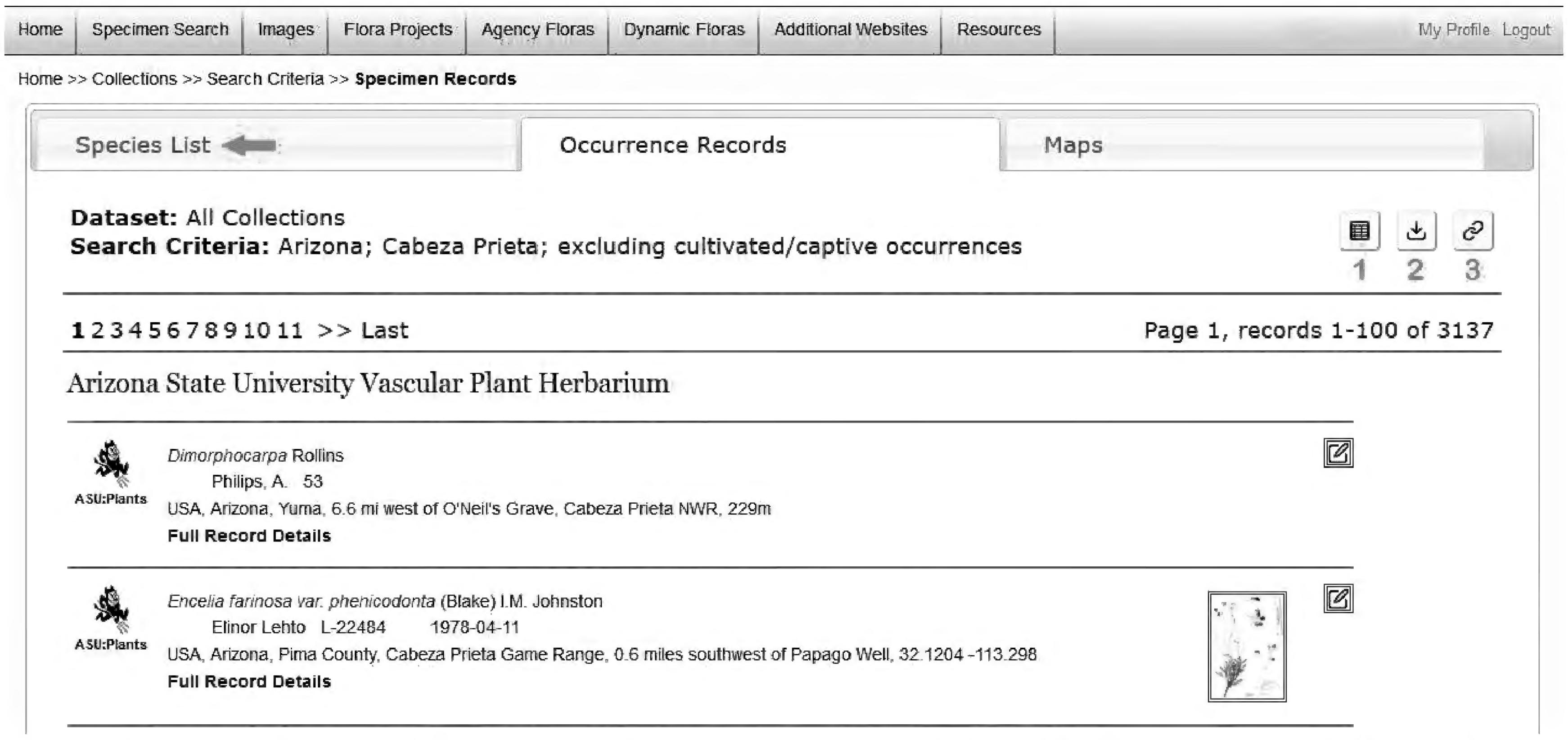



**Figure 4.** List display of Occurrence Records. Arrow indicates the "Species List" tab which converts "Occurrence Records" to a list of species. Button 1 changes output to Table Display (Table 2), button 2 allows you to download the data of all the specimens as a CSV file, and button 3 copies the checklist address to the computer memory and can be saved or sent to someone else.

**Example of a Locality search**. Cabeza Prieta National Wildlife Refuge, Arizona

The Species List tab presents a total Taxa Count denoted in bold above the list (Fig. 5). However, if you look at the Taxonomic Filter you will see that this count is generated from the raw data (taxonomy is unresolved) and may not account for species synonyms or typos, thus creating an inaccurate count of taxa. To adjust this, click the Taxonomic Filter and select a Thesaurus applicable to your region from the dropdown menu. For areas within Arizona, such as the locality used in this example of Cabeza Prieta, it is suitable to use the ASU Taxonomic Thesaurus. For areas outside of Arizona you may want to select between the Central Taxonomic Thesaurus and Integrated Taxonomic Information System (ITIS) Thesaurus. In the example in Fig. 5, the number of taxa was reduced from 712 to 673 after application of the ASU Taxonomic Thesaurus. This is because the filter identifies and consolidates species by their synonyms and removes specimens identified to family or genus only.

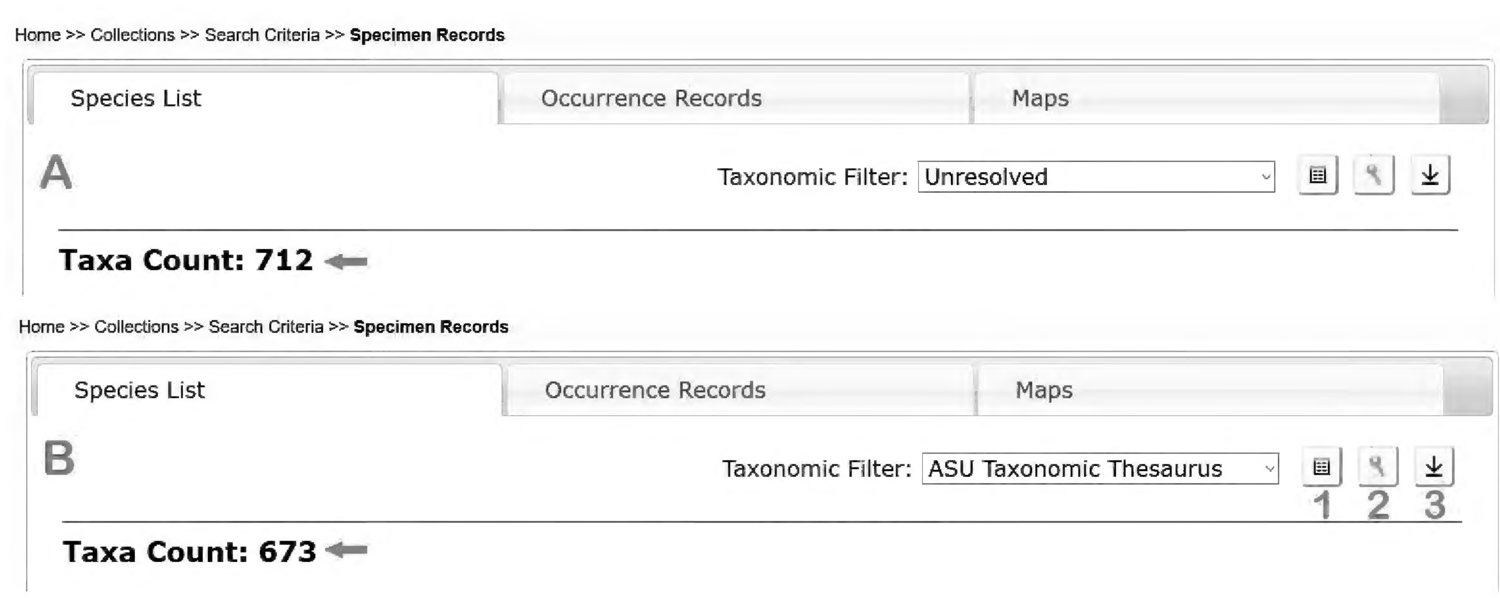



**Figure 5.** Species list display showing numbers of taxa using "Unresolved," i.e., raw data (A) and using the ASU Taxonomic Thesaurus (B). Button 1 leads to Checklist Explorer, button 2 leads to an interactive key, and button 3 downloads the checklist data as a table of taxa.

Checklists can also be made with the Latitude and Longitude options (Fig. 3) that involve establishing a bounding box, polygon, or circle of choice. A word search using "Locality Criteria" and a search based on "Latitude and Longitude" may give somewhat different lists of specimens and taxa depending on how many specimens are georeferenced within that area. To search by Latitude and Longitude, click the Map icon in the top right-hand corner of the box for Bounding Box, Polygon, or Point-Radius, corresponding to your desired search option.

Once you have clicked the map icon, a new window will pop-up with a map and four buttons located on the top (Fig. 6). The first button, symbolized by a hand, allows you to move through the map to select a location without drawing a polygon or circle. The second button, symbolized by a V-shaped polygon, allows you to draw an irregular polygon. The third button, symbolized by a box, allows you to draw a bounding box. The last button, symbolized by a circle, allows you to place a point and establish a radius around the point to include. Begin by using the hand symbol and the plus or minus symbols to adjust the map and zoom into the area you are interested in. To draw a box or a circle, click near the general area of interest and drag the pointer to expand the shape to desired coverage. Edit your circle or box by hovering over one of the points on the shape perimeter then clicking and dragging to expand or contract the shape. To draw an irregular polygon, use single clicks to create points (vertices) of your polygon. Complete the polygon by linking back to the original point or double clicking. You may move any outlined shape by using the hand symbol. Once you have outlined your area of choice, click the "Save and Close" button at the top right-hand corner of the window and the defining coordinates will be saved.

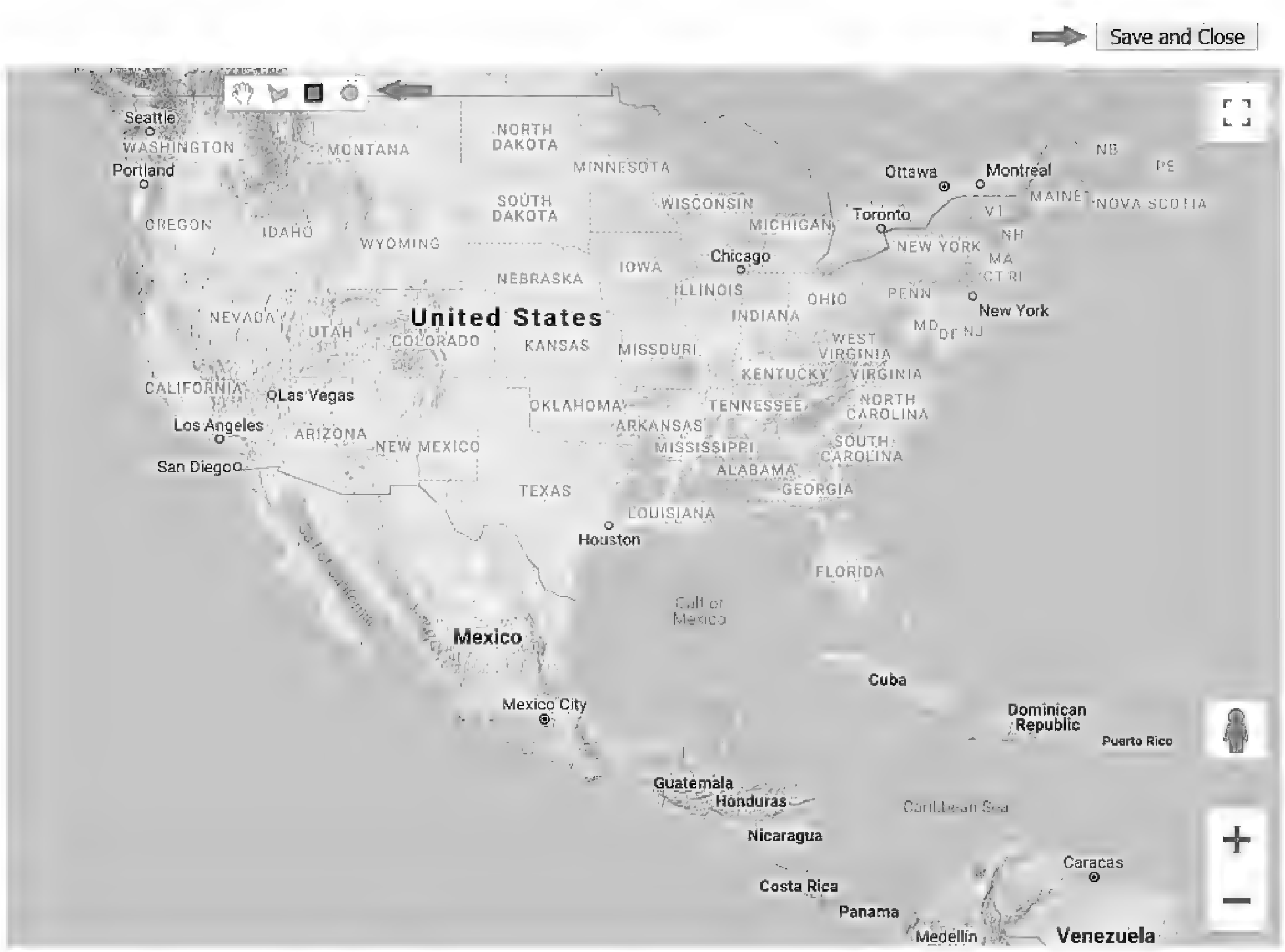



**Figure 6.** Map search view. Arrow on left points to tools for creating box, polygons and circles. Click the hand symbol for panning round the map, V-shaped polygon for creating irregular polygons, box for creating a bounding box, and circle for creating a point-radius circle. Arrow on right points to button to save coordinates.

For this example, we used the irregular polygon tool to outline Cabeza Prieta National Wildlife Refuge and generate a checklist for specimens georeferenced within those boundaries (Fig. 7).

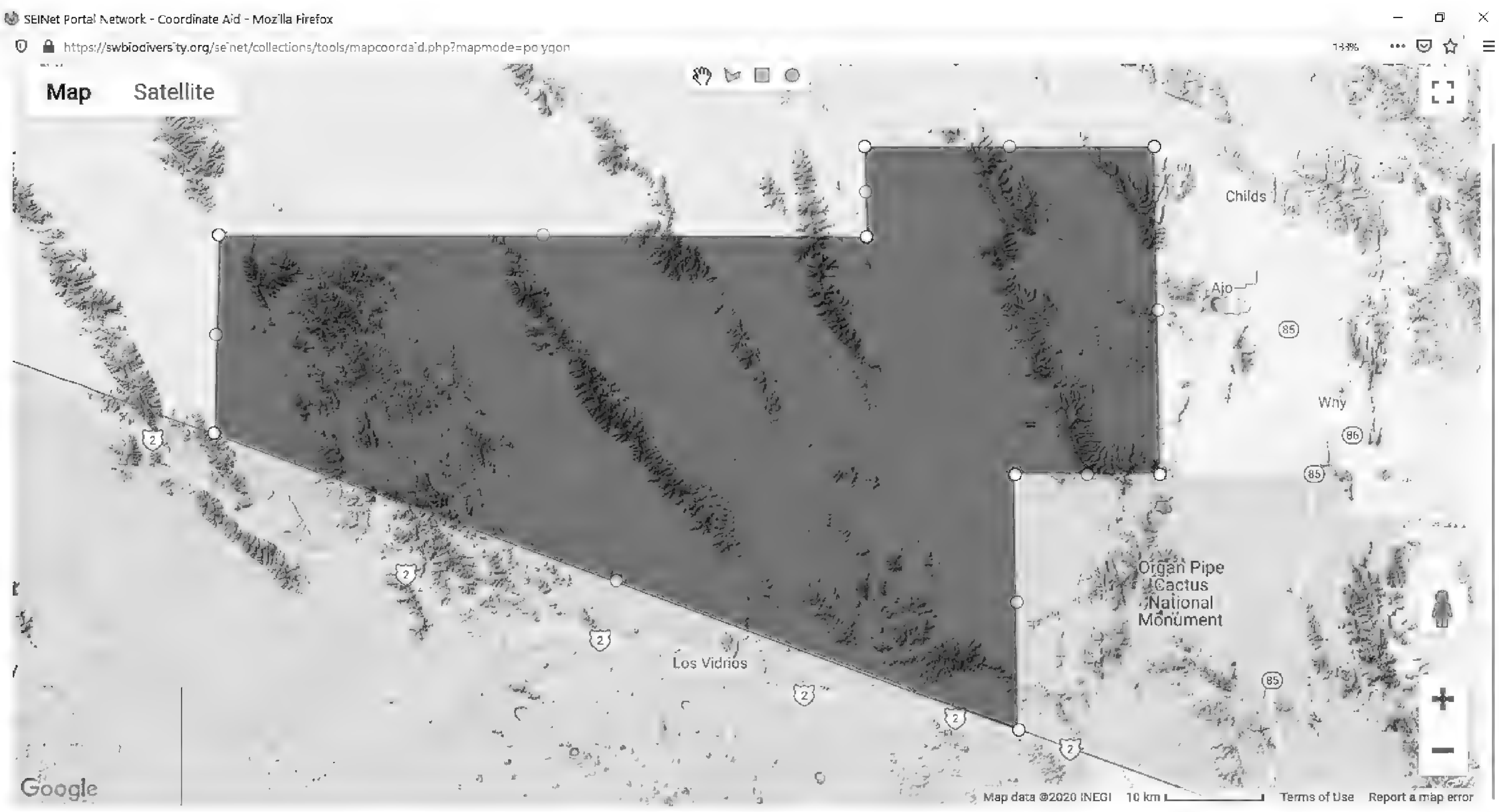



**Figure 7.** Irregular polygon map search outlining the boundaries of Cabeza Prieta National Wildlife Refuge.

Once you have generated your results in List Display there are additional options available to manipulate the display or search within your checklist. The three tools available via the three buttons to the right of the taxonomic filter (Fig. 5) are described below.

***Checklist explorer interface***: This option (button 1, Fig. 5) generates an interactive checklist that offers a number of different ways to view the list (Fig. 8). Clicking this button will open a new page with an "Options" box in the right-hand side of the screen. To modify the display, check the box next to your preferred display options in this box and then click "Build List". For example, you may want to include common names or images if you plan to use the list as a quick field guide. You may limit the checklist taxonomically by inserting, for example, a genus or family name in the box under "Search". The checklist interface defaults to organizing by family and alphabetizing genus within family but clicking "Show Taxa Alphabetically" will alphabetize all taxa. Once you have selected your preferred display options, you can click button 1 to export to a Word document, button 2 to Print from Browser, or button 3 to download the list as a CSV file that may be opened in Excel, Numbers, Access and other spreadsheet compatible applications (Fig. 8).


**Figure 8.** Checklist explorer interface. Arrow to the right of the Specimen Checklist title indicates the interactive key accessible through this interface. The options box on the right-hand side of the page allows searching within the checklist, filtering, and adjusting the checklist display. The arrow within the Options box indicates three options: 1) Export the checklist as a Microsoft Word document, 2) Print the checklist in browser, or 3) Export the checklist from browser to your computer as a CSV file that may be opened in Excel, Numbers, Access and other spreadsheet compatible applications.

***Interactive key interface***: This option (button 2, Fig. 5) allows you to key out taxa on your checklist based on observed morphological features (Fig. 9). This example includes a checklist generated from a locality search of Great Smoky Mountains National Park, North Carolina. By checking boxes of known features such as leaf arrangement, flower color, plant habit, etc. the checklist is reduced to indicate possible matches from within a subset of your list. Note that the accuracy of these keys is limited by the character state data that are available in the Symbiota portal.

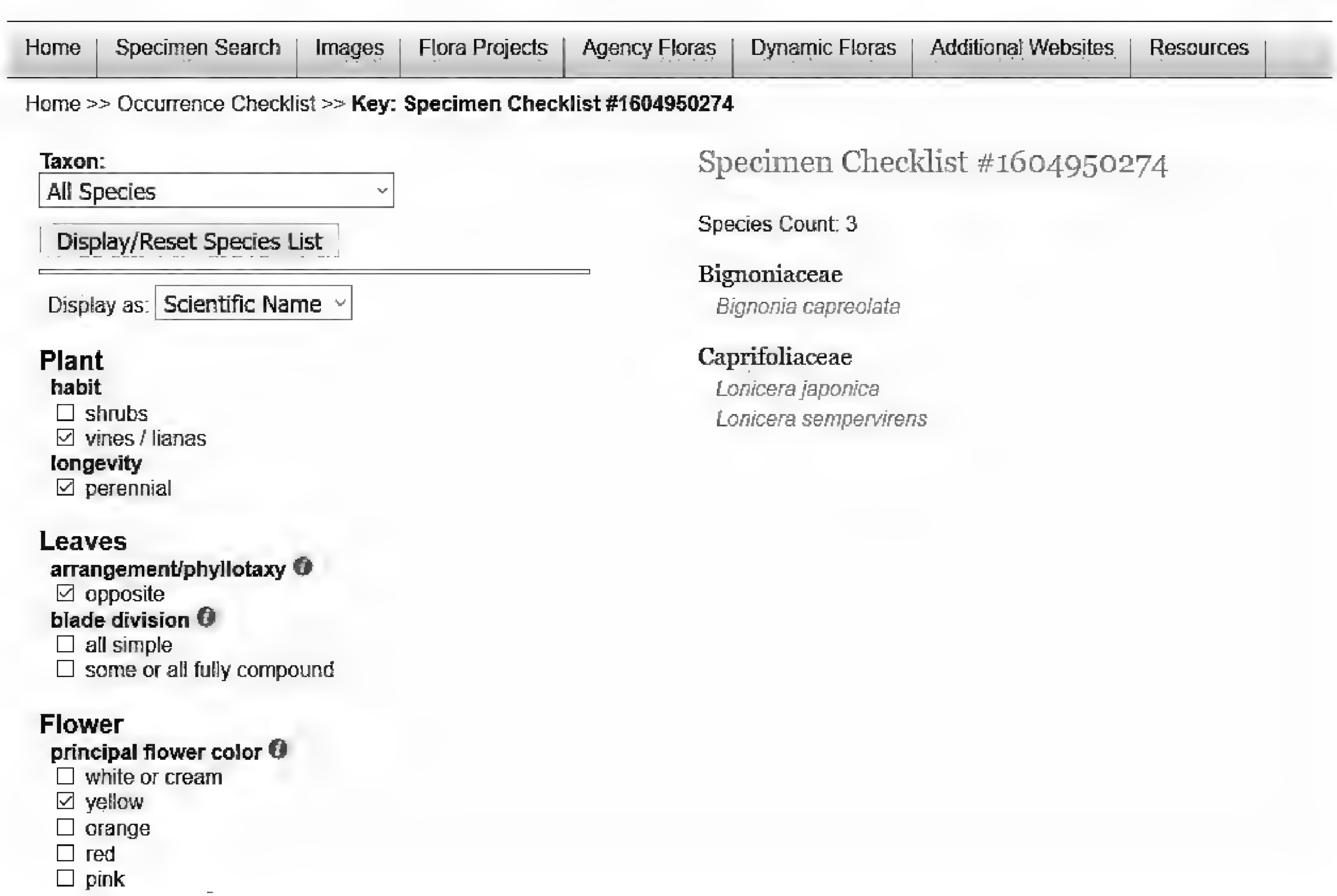


**Figure 9.** Interactive Key Interface assists in identifying taxa based on observed morphological characteristics. In this case the characters of perennial, vine, leaves opposite, and flowers yellow produced a list of three taxa.

***Download checklist data***: This option (button 3, Fig. 5) allows you to download a Comma Delimited (CSV) file and compare it with other checklists via Excel or other programs such as Access. When you click this, a new window will pop up with the default options: Comma Delimited (CSV), ISO-8859-1 (western), and Compressed ZIP file selected (Fig. 10). We will use these options. Once you unzip and open the CSV file you can export it to your software of choice (File > Export To > Excel, Numbers, Access, etc.) for an easier platform in which to work with the data (Fig. 11). To keep track of data, consider naming the file after the locality you downloaded.

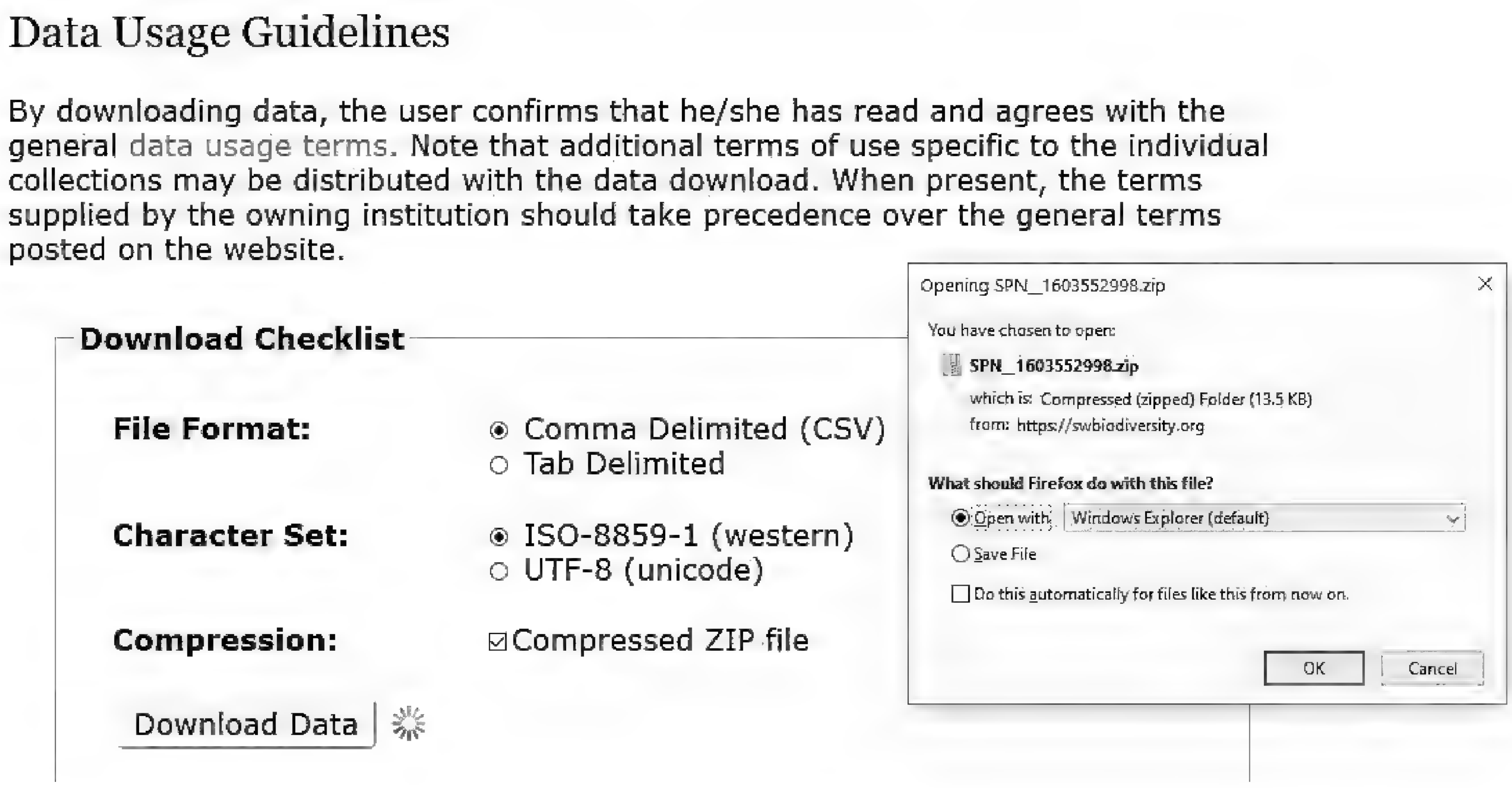



**Figure 10.** Pop-up window for downloading checklist data. Data will download as a CSV zip file; click OK to save to computer.

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | family | scientificName | genus | specificEpithet | taxonRanl | infraSpecificEpithet | scientificNameAuthorship |
| 2 | Acanthaceae | Carlowrightia arizonica | Carlowrightia | arizonica | | | A. Gray |
| 3 | Acanthaceae | Justicia californica | Justicia | californica | | | (Benth.) D. Gibson |
| 4 | Amaranthaceae | Amaranthus crassipes | Amaranthus | crassipes | | | Schlecht. |
| 5 | Amaranthaceae | Amaranthus crassipes var. crassipes | Amaranthus | crassipes | var. | crassipes | Schltdl. |
| 6 | Amaranthaceae | Amaranthus fimbriatus | Amaranthus | fimbriatus | | | (Torr.) Benth. ex S. Wats. |
| 7 | Amaranthaceae | Amaranthus fimbriatus var. denticulatus | Amaranthus | fimbriatus | var. | denticulatus | (Torr.) Uline & Bray |
| 8 | Amaranthaceae | Amaranthus palmeri | Amaranthus | palmeri | | | S. Watson |
| 9 | Amaranthaceae | Atriplex | Atriplex | | | | L. |
| 10 | Amaranthaceae | Atriplex canescens | Atriplex | canescens | | | (Pursh) Nutt. |
| 11 | Amaranthaceae | Atriplex elegans var. fasciculata | Atriplex | elegans | var. | fasciculata | (S. Wats.) M.E. Jones |
| 12 | Amaranthaceae | Atriplex pacifica | Atriplex | pacifica | | | A. Nels. |
| 13 | Amaranthaceae | Atriplex polycarpa | Atriplex | polycarpa | | | (Torr.) S. Wats. |
| 14 | Amaranthaceae | Atriplex semibaccata | Atriplex | semibaccata | | | R. Br. |
| 15 | Amaranthaceae | Chenopodiastrum murale | Chenopodiastrum | murale | | | (L.) S. Fuentes-B, Uotila & Borsch |
| 16 | Amaranthaceae | Chenopodium desiccatum | Chenopodium | desiccatum | | | A. Nels. |
| 17 | Amaranthaceae | Monolepis nuttalliana | Monolepis | nuttalliana | | | (Schult.) Greene |
| 18 | Amaranthaceae | Salsola tragus | Salsola | tragus | | | L. |
| 19 | Amaranthaceae | Suaeda nigra | Suaeda | nigra | | | (Raf.) J.F. Macbr. |
| 20 | Amaranthaceae | Tidestromia lanuginosa | Tidestromia | lanuginosa | | | (Nutt.) Standl. |
| 21 | Amaryllidaceae | Allium macropetalum | Allium | macropetalum | | | Rydb. |
| 22 | Anacardiaceae | Rhus kearneyi | Rhus | kearneyi | | | Barkl. |
| 23 | Anacardiaceae | Schinus terebinthifolius | Schinus | terebinthifolius | | | Raddi |

**Figure 11**. Example CSV file opened as an Excel sheet from downloaded checklist data. Columns are broken into family, scientific name, genus, specific epithet, and authorship.

## DYNAMIC FLORAS TAB

An additional way to create a checklist is to use the Dynamic Floras Tab located on the grey toolbar on the top of any Symbiota-based portal (Type A homepage) or left side (Type B homepage). This tool is essentially a checklist or key generated from a point-radius search. However, this method skips a number of checklist-creating steps.

When you click either Dynamic Checklist or Dynamic Key in the dropdown menu from the Dynamic Floras tab, you will be prompted to a map view. From here, use the zoom tool and hand to pan across the screen and drop a pin in the desired location. You can modify what is included in your search such as limiting to a specific family or genus using the "Taxon Filter" box, though this box is not a required field. Once you have your location selected and optional filter applied, click the box titled "Build Checklist" (Fig. 12). This technique is advantageous as a quick field guide reference. For example, use this method if you recognize an unknown organism to genus or family but would like to compare photos or use a key filtered to that taxon.

If a radius is defined, taxon lists are generated using observations and specimen data collected within the defined area (Gilbert, pers. comm.). If a radius is not supplied, the area is sampled by progressively increasing the radius by up to 9 steps of 10 miles each. Once a sample of 2500 taxa is reached, a good example of local diversity, the search is stopped. In other words, poorly collected areas will have a larger radius sampled. The maximum radius is 90 miles or 145 km.

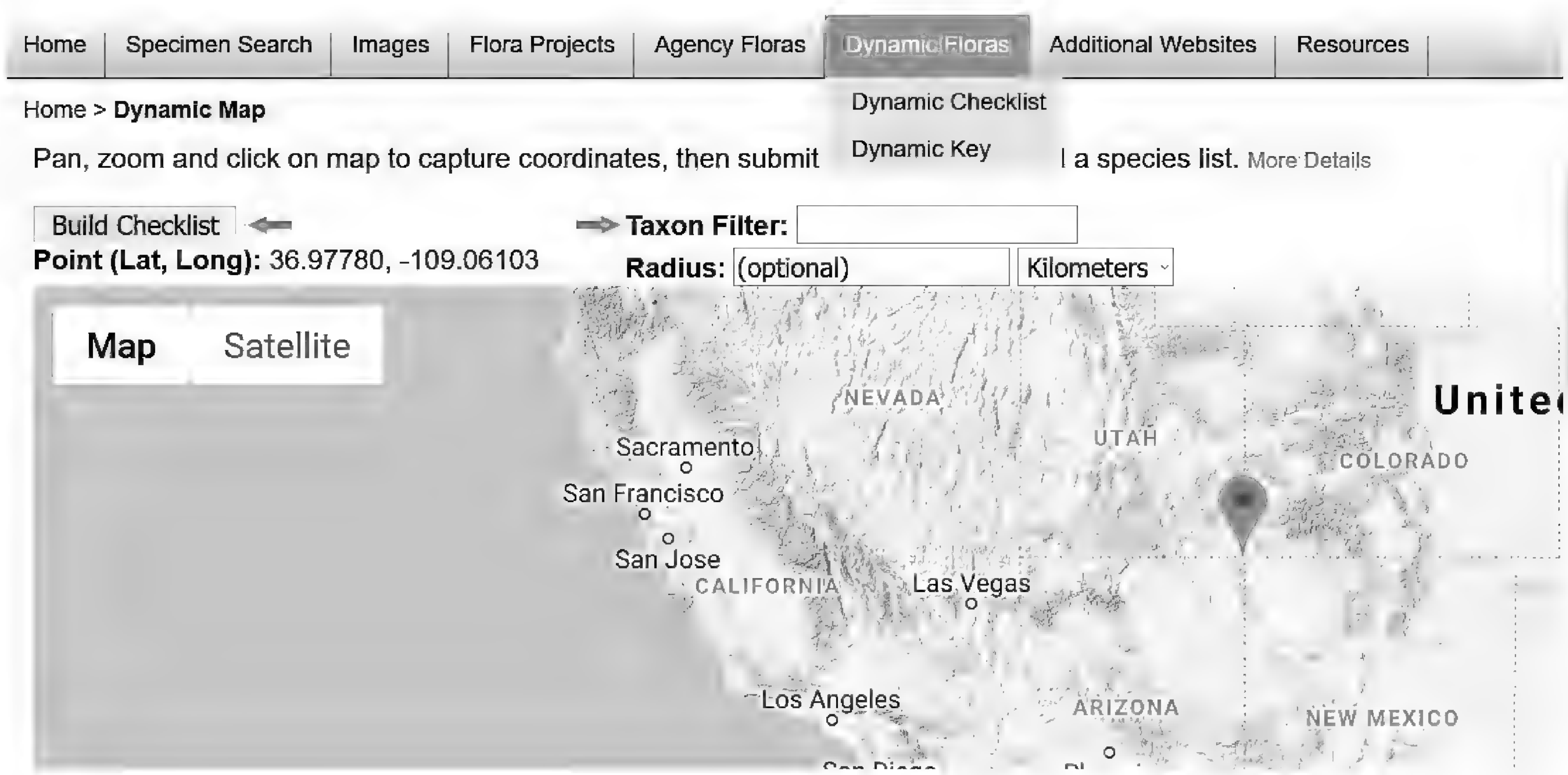



**Figure 12.** Creating a checklist or key with the Dynamic Flora tool. Dynamic Floras tab located is on the top toolbar of Type A Homepages, click "Dynamic Checklist" to create checklist. Pan, zoom, and click on the map to capture coordinates. Click the "Build Checklist" button to proceed. The Taxon Filter allows filtering the checklist to a specific family or genus prior to generating the search.

## SAVED CHECKLISTS, PERSONAL AND PUBLIC

Until now, the options discussed for creating checklists have been temporary or downloaded checklists that are not saved to a portal. However, it is possible to create checklists that are saved and can be revisited via the Symbiota portal you are using. Saved checklists can

be continually updated over time, can be linked to specimen records, and can be shared with the public.

A personal checklist generally begins as a private checklist created on a Symbiota portal such as SEINet AZ-NM Chapter and saved to “My Profile” for future access via that portal. A private checklist may be made public on a Symbiota site for the use of different agencies, education groups, and/or the general public.

A user account is required for creating saved checklists within any Symbiota portal. If you do not have an account, you can obtain one by clicking on “New Account” in the upper right corner of the opening page of SEINet Arizona-New Mexico Chapter (Type A format). Other Symbiota portals (Type B format) such as Intermountain Regional Herbarium Network or North American Network of Small Herbaria have this information on a left-hand sidebar. Once you click this, a form appears, and you need to provide name and email and create a login and password. Once your login information is established you will automatically be signed in. This login is accepted across all sites within the SEINet Portal Network. For a list of these portals, visit the SEINet Arizona-New Mexico Chapter homepage and locate the bulleted list at the bottom of the page.

There are many reasons for creating personal or public checklists including

- Inventories for government agencies such as the National Park Service or Forest Service
- Field contractors working on vegetation projects
- Graduate student floras
- Teaching classes
- Personal knowledge prior to visiting a new area

Public checklists can be added to any of the Biotic Inventory Projects listed within the Sitemap or the menu toolbar upon request. There is some overlap in the checklists that appear on the menus of SEINet portals. Simply hover your mouse over the Flora Projects tab or Agency Floras and select an option from the dropdown menu. On the SEINet Arizona–New Mexico Chapter homepage options include Arizona, New Mexico, Colorado Plateau, Plant Atlas of Arizona (PAPAZ), Sonoran Desert, or Teaching Checklists (Fig. 13).

After you select a category of projects from the dropdown menu, the next page displays all the public checklists created under that category. Select a project that interests you; in this example we selected “Antelope Island State Park” from the Teaching Checklists category (Fig. 14). If you look to the right of the title of the checklist selected, each project has an interactive key (denoted by the key symbol) and an automatically generated name game and flash card quiz (Fig. 15). These are useful educational tools to help with the identification process of specific taxa within an area.


**Figure 13.** Public checklists are organized within the Inventory Projects typically available in the dropdowns listed within top menu (e.g., Flora Projects and Agency Flora tabs). Red arrow indicates the tab to hover over to see the drop-down menu options.

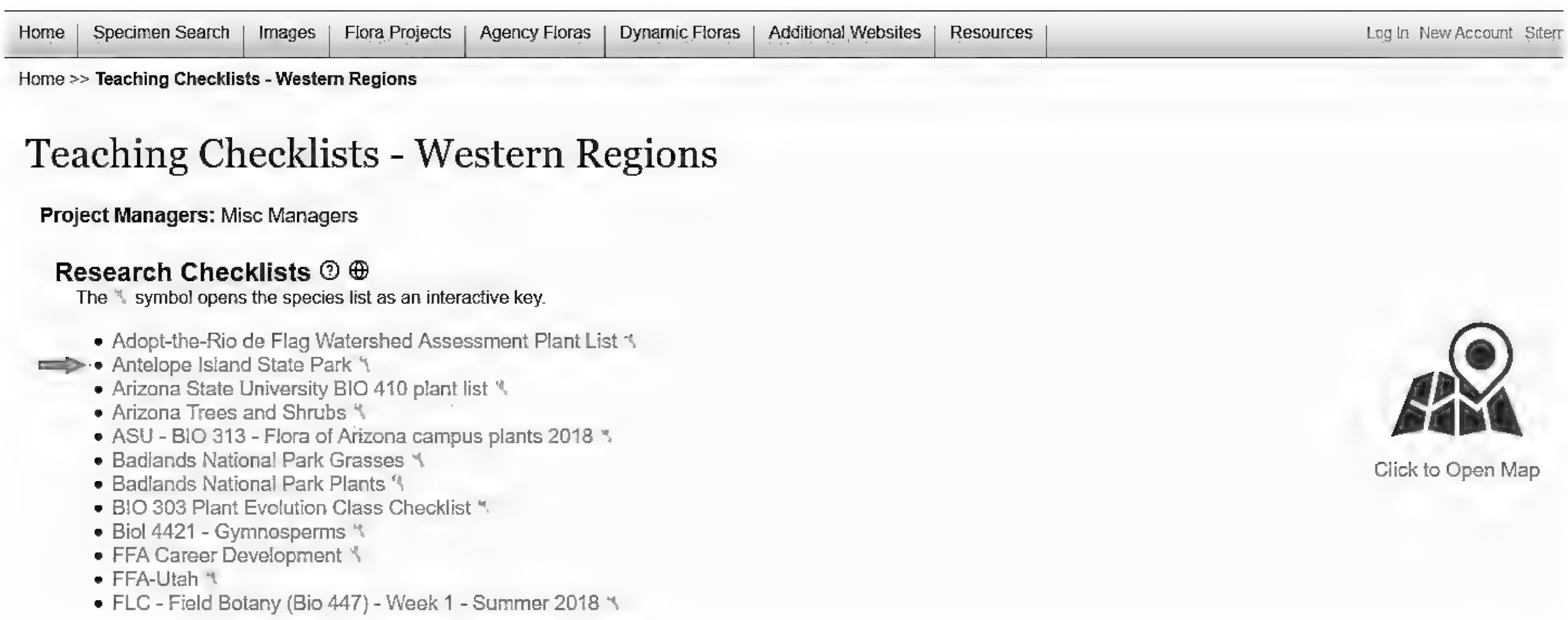



**Figure 14.** Teaching Checklists category of public checklists. Red arrow indicates link-choice for "Antelope Island State Park", the example checklist.

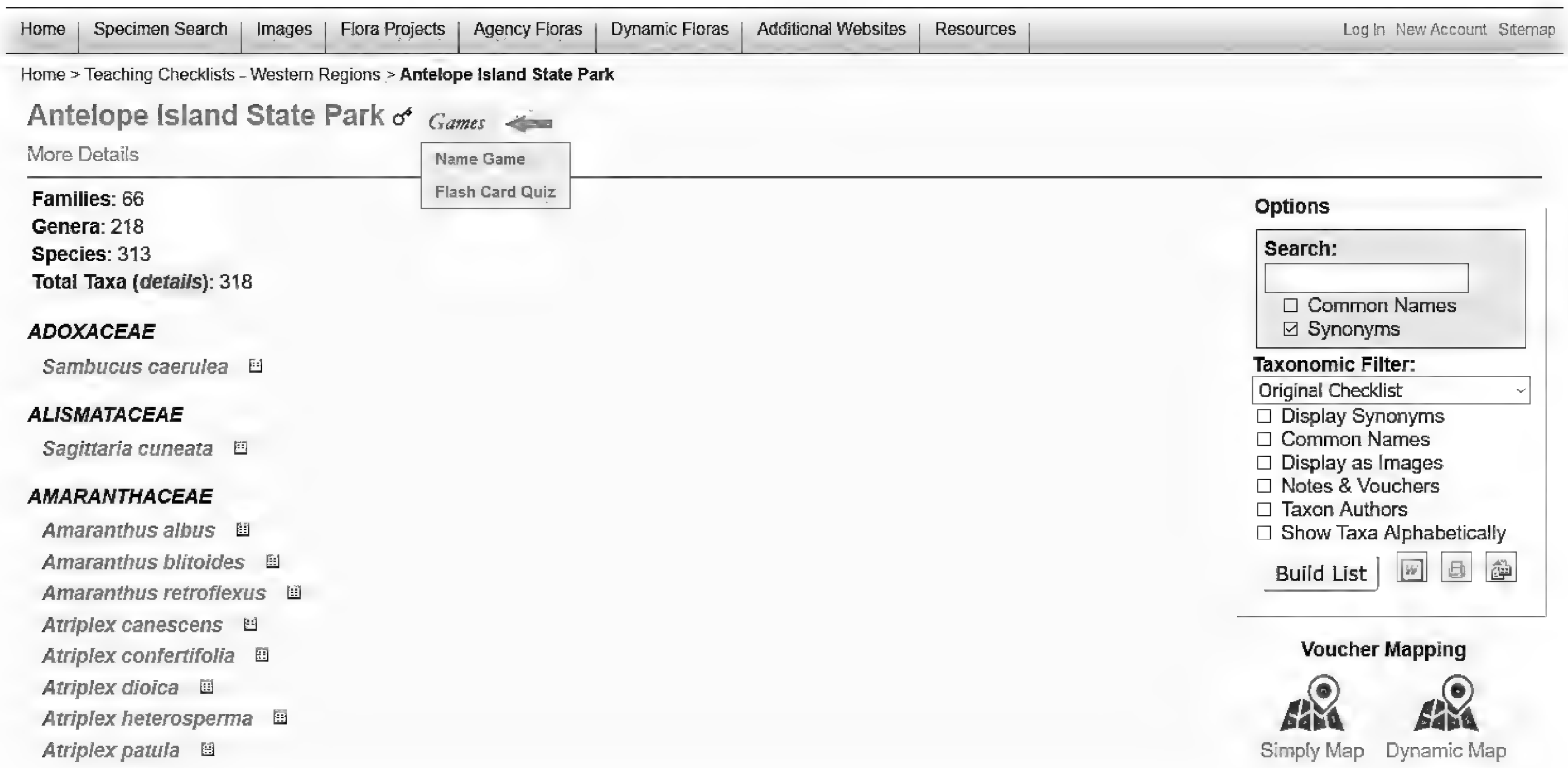



**Figure 15.** Example public checklist "Antelope Island State Park". Red arrow indicates the Key symbol (leads to an Interactive Key available for the checklist) and the Games located to the right of the checklist title. There are two options for games: Name Game and Flash Card Quiz.

## How to create saved checklists on SEINet/Symbiota websites

Click on "My Profile" located on the right of the grey toolbar at the top of the page (Type A sites) or left column (Type B sites) for other Symbiota sites. The page will default to the "Species Checklists" tab. From this tab, follow the hyperlink "Click here to create a new checklist", or click the green plus (+) symbol to begin creating a checklist (Fig. 16).

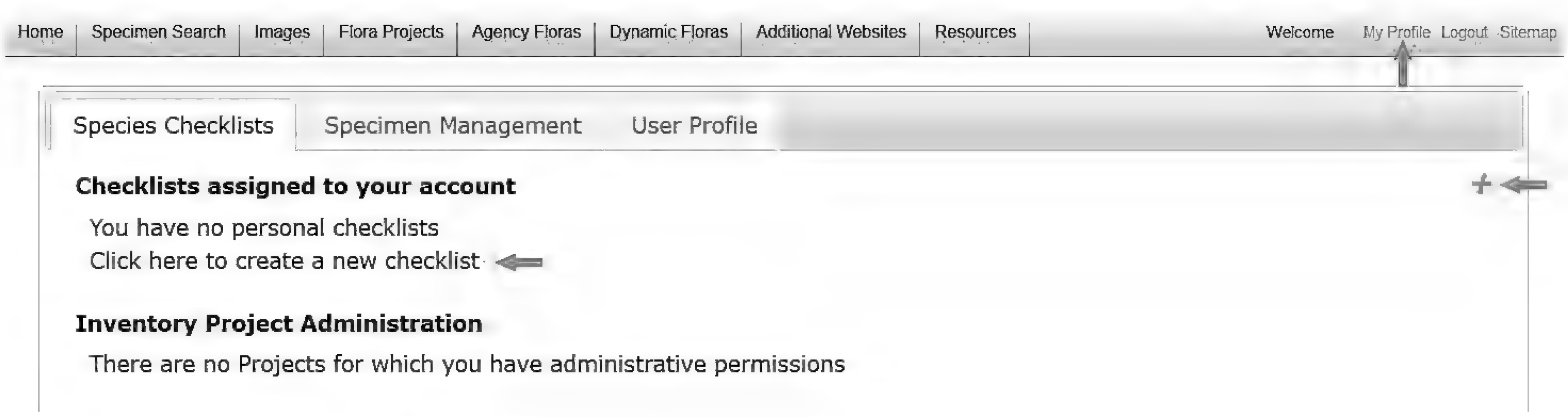



**Figure 16.** Introduction to creating a saved checklist on a Symbiota website, browser view after clicking "My Profile" on a Type A site. Vertical red arrow points to the Type A location for "My Profile" link-choice. Horizontal red arrows indicate two options for creating a new checklist.

The resulting page is a form where you can record important metadata about your checklist (e.g., authors, abstract). The only required field is the checklist name, but providing authorship and locality is recommended. This form may be edited later. It is also possible to define a latitude, longitude, and uncertainty radius or a polygon footprint for your checklist. You may also toggle the accessibility of your checklist between private (default; open only to you or anyone you share the direct link with) or public (available to be added to an Inventory Project). Once you have entered the Checklist name and any other information you wish to add, click on "Create Checklist" at the bottom of the page (Fig. 17). If you make your checklist public you may want it assigned to some specific project (e.g., teaching checklists, regional flora projects). Note, assignments to specific projects require help from portal administrator

or managers of the inventory projects and checklists must be adequately developed in order to be accepted as a public checklist.

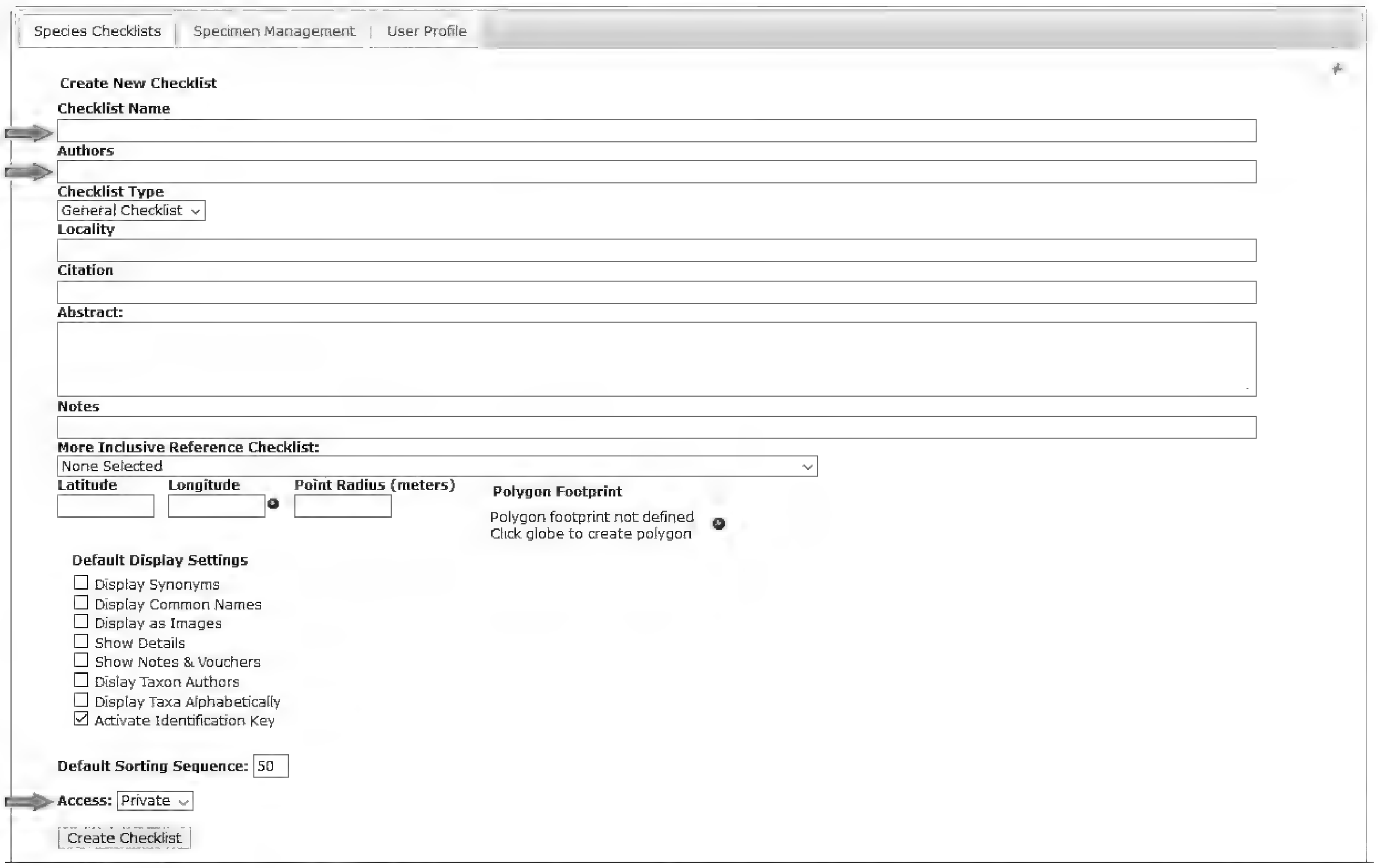



**Figure 17.** Create new checklist form. Red arrows indicate the fields that are recommended to fill out: Checklist name (required), Authors, and Access (private or public).

If you already have a list of taxa you wish to include in your checklist, there are two main methods for adding taxa to a checklist after you have filled out the Create New Checklist form. You can either ***manually add taxa individually*** or ***batch upload a spreadsheet*** of several taxa all at once. Both of these options can be accessed via the "Add Species to List" box below the Options box (Fig. 18). If this box is not visible, click the drawing symbol (pen and paper) icon with "spp" in the top right corner of the page. The batch upload option is recommended for most saved checklists because it is efficient at capturing a large number of taxa in well-documented locations. The two options can be used in combination if the batch upload fails to capture all the taxa that you want on your list. It is important to note if a taxonomic name does not already exist in the Symbiota portal's taxonomic thesaurus or is misspelled, an error will result from attempting to add that name. You will need to contact your portal administrator about adding the name to the thesaurus or ensure you are spelling it correctly before it can be added to your checklist.

***Manual upload—Single Species***: If this is a new checklist, without any taxa, you see a screen as shown in Fig. 18. "Taxon" will appear just below "Add Species to List" (red arrow). Enter the scientific name of the taxon you wish to add. As you type, a drop-down menu for taxa with similar names is automatically generated. Select the desired name from the drop-down menu. The "Taxon:" text window is the only required field for adding taxa, but there are additional fields into which you may add information about the taxon's habitat, abundance, etc. as they pertain to your checklist. Proceed by clicking "Add Species to List". Repeat this process for

each individual taxon. Once you have one or more checklists in your Profile, you may click on the name of a checklist to edit data or add more taxa using buttons 1, 2, and 3. These options will be discussed below.


**Figure 18.** How to add taxa to a saved checklist and options for editing a checklist. This image shows an empty Checklist ("No Taxa Found"). Red arrow indicates the box for either manually adding taxa or batch uploading a spreadsheet. Blue arrow indicates the button to proceed with adding a single taxon using the text boxes above. Green arrow indicates the option for adding multiple taxa at a time from a taxon list saved as a spreadsheet. Red numbers 1-3 are options for editing a checklist: 1) Checklist Administration, 2) Manage Linked Vouchers, and 3) Edit Species List.

***Batch upload a spreadsheet—Multiple species***: One way to obtain a spreadsheet compatible for upload is to download a checklist CSV file from a search generated on a Symbiota site as described on page 9 and illustrated in Fig. 11. Instructions for this procedure are described in the section "How to make Checklists with the SEINet database" on pages 3 to 9 above. The essential field for a batch upload is "scientificName" (Fig. 11, column B). Any CSV spreadsheet that has that field will work for a batch upload. Note that the file must be in CSV format, but an Excel spreadsheet for instance with an xlsx extension can be converted to a CSV file using the "Save as…" function. Switch back to the original tab under "My profile" for adding taxa to your checklist. If the Checklist has some taxa entered already you will have to click on "spp" button (Fig 18, red 3). Click "Batch Upload Spreadsheet" (Fig. 18, green arrow) at the bottom of the cream-colored box. Click "Choose File" ["Browse…"] and select the CSV file you have prepared; Taxonomic Resolution can remain as "Leave Taxonomy as Is". Proceed by clicking "Upload Checklist" (Fig. 19). The next page (not illustrated here) displays a bulleted list describing the upload status of the list. Some errors may occur that you may want to read through. These are typically duplicate entries that can be ignored. As previously mentioned, if some names fail to upload, you can use the single species method to manually add them to your list. To view and/or edit your saved checklist, click "Proceed to Checklist" in the last bullet.

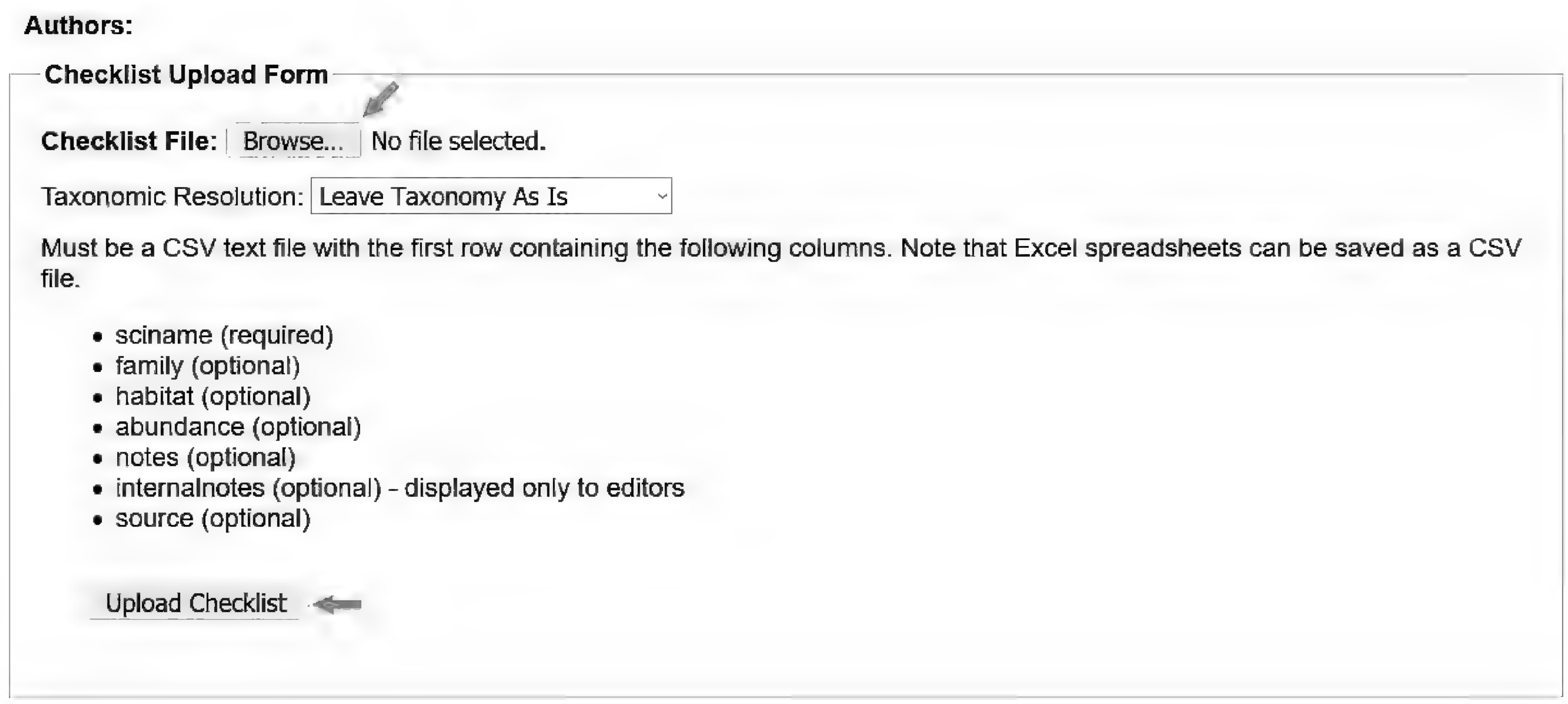



**Figure 19.** Checklist Upload form to Batch Upload a Spreadsheet. Red arrows indicate how to attach a file and upload.

To edit a saved checklist, locate the three icons in the top right corner of the generated checklist (Fig. 18, red 1-3): 1) Checklist Administration, 2) Manage Linked Vouchers, and 3) Edit Species List. The second choice, Manage Linked Vouchers, is the most complex so we discuss it last.

***Checklist Administration***: Drawing Symbol (pen and paper) + A (Fig. 18, red 1)
Selecting this option leads to a new page with three tabs located underneath the checklist title. The first tab, **Admin**, allows you to add an editor or to delete the checklist. The **Description** tab allows you to modify the checklist description notes. The **Related Checklists tab** allows you to establish hierarchal relationships between checklists so information in one may be transferred to another.

***Edit Species List***: Drawing symbol + spp (Fig. 18, red 3)
This option allows you to add and delete taxa manually or upload spreadsheets for multiple taxa (See previous section).

***Manage Linked Vouchers***: Drawing Symbol + V (Fig. 18, red 2)
You may want to link vouchers of specimens for taxa on your checklist. This is helpful if you are preparing and collecting for a specific flora project. Vouchers, which serve as the documentation of floras, should be specimens collected and identified by yourself or specimens known to you to be correctly identified by experts.

## BUILDING A CHECKLIST FROM SPECIMEN RECORDS

You can populate (or build) a checklist using the Manage Linked Vouchers tool that pulls existing specimen records for your taxon list. Go to My Profile and click on the name of an existing checklist or create a new checklist as described above. On the next page, as shown in Fig. 18 (an empty checklist or one populated with some names), click Manage Linked Vouchers (Fig. 18, red 2). If the checklist is new or has no criteria in the Search Statement,

the resulting page displays a search term box titled "Edit Search Statement" to enter criteria (Fig. 20). If the "Search Statement" contains criteria already, you are directed to the New Vouchers tab (Fig. 21). Clicking on the pencil icon toggles the display of the Edit Search Statement page editing panel.

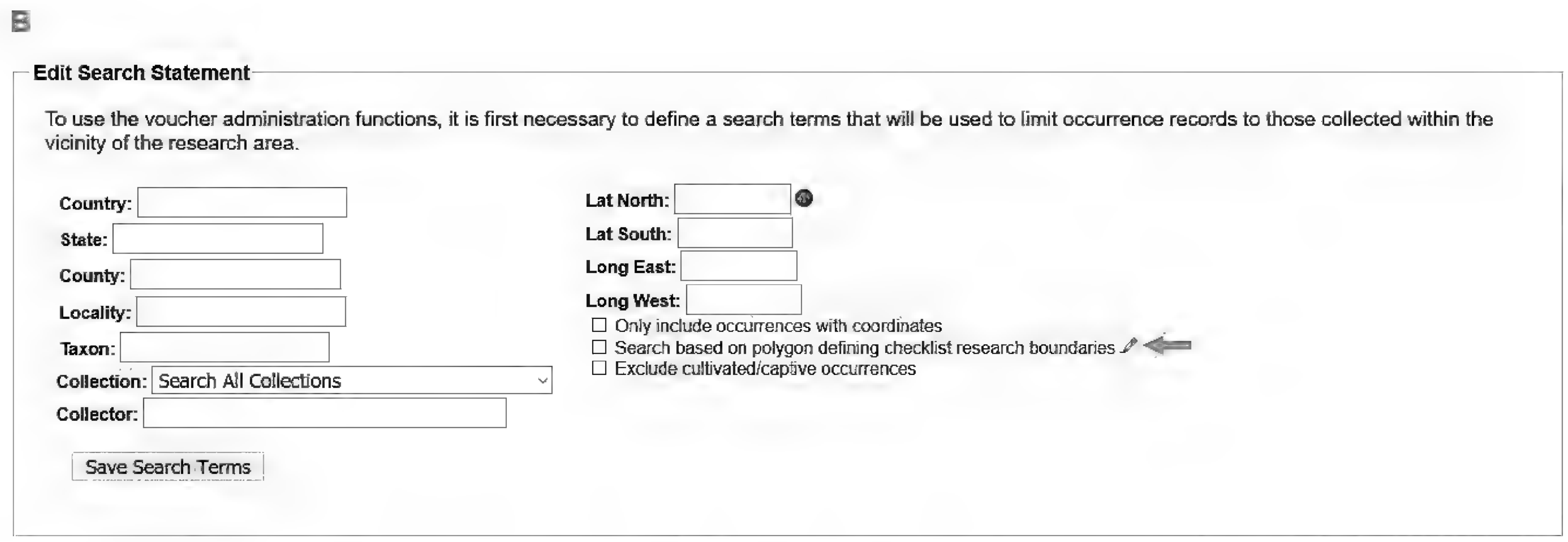



**Figure 20.** Search term box for creating a checklist from Manage link vouchers tool. Red arrow indicates the bullet point to check and pencil to click in order to draw a polygon.

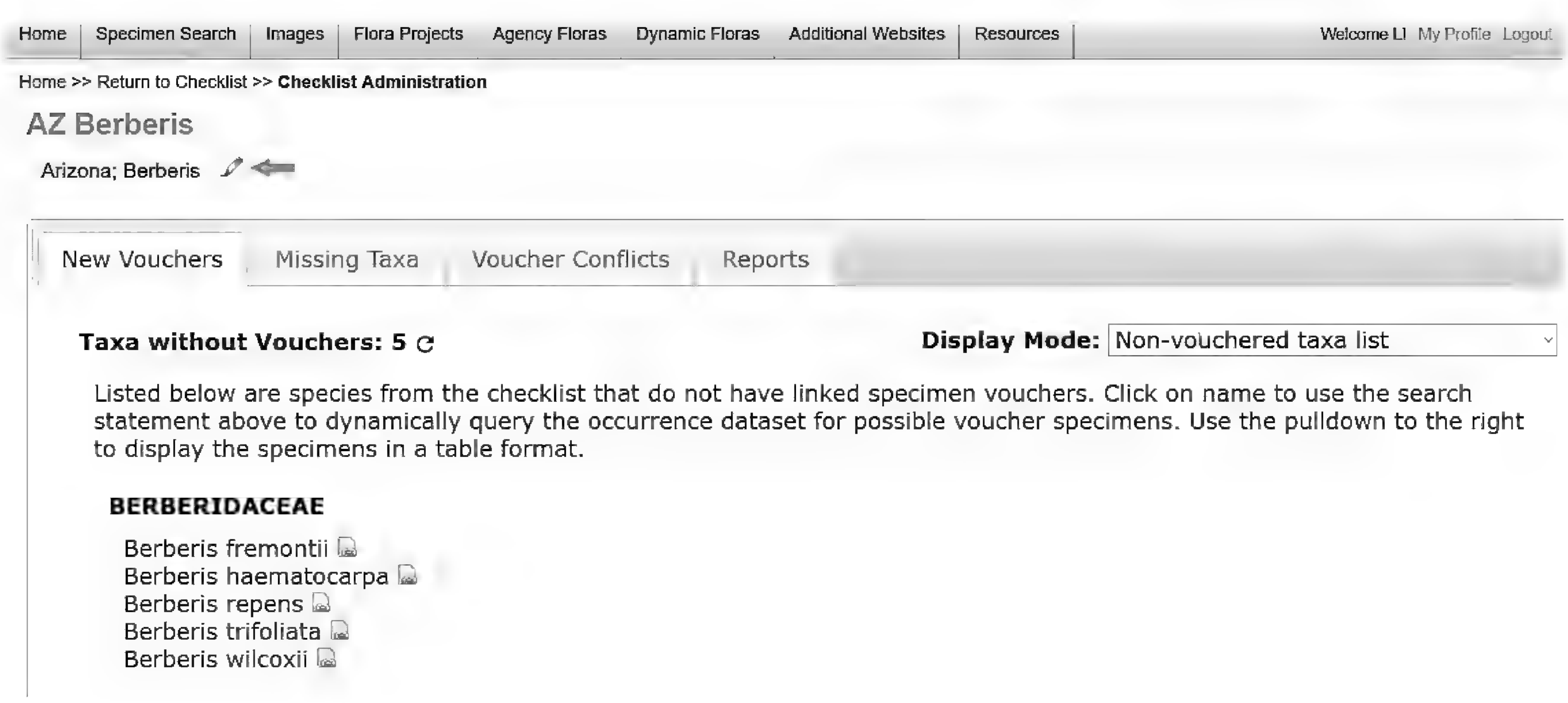



**Figure 21.** The page generated from clicking on the "Managed Linked Vouchers" button if the checklist already contains some information in the boxes of the Search Statement. The arrow indicates the pencil icon that when clicked, directs you to the page in Fig. 20. In this case the search criteria are taxon equal to *Berberis* and state equal to Arizona. There are 5 taxa without vouchers. Clicking on the icon to the right of each name leads you to potential voucher specimens.

There are three options for the Search Statement in which you may: 1) use the text boxes for a locality search, 2) enter coordinate data using the mapping tool (a globe or similar icon) to create a bounding box, or 3) search using a polygon (select the box "Search based on polygon defining checklist" and click the pencil symbol to the right to enter map view with the polygon tools). If searching using text terms, typically try to limit the search to state and one other defining feature (e.g., collector)—fewer terms facilitate a more inclusive search. If drawing a polygon, make sure the browser is expanded to full page and click the button "Save Polygon" at the bottom of the page when finished (Fig. 22). Using a bounding box or polygon search will automatically exclude specimens that have not been georeferenced. Note that the

point-radius circle option and searching by date or elevation are not available within this Search Statement tool. To add these options, refer to the "Batch Upload" technique discussed earlier on page 16. Note also that it is possible to return and alter the Search Statement repeatedly to compile a checklist consisting of multiple variables. For instance, you might want to create checklists based on a few different collectors or spelling variants of a locality.

Once the search is properly defined, click "Save Search Terms" button to proceed. At the top of the next page (Fig. 21) there are four tabs. We will only discuss the first two tabs. The first tab on the left, "New Vouchers", lists taxa records that do not yet have linked voucher specimens (Fig. 21). The second tab labeled "Missing Taxa" (Fig. 23), lists taxa that are vouchered within your search area, but are missing from your checklist. In order to populate your checklist, you must move the specimens from the "Missing Taxa" to the "New Vouchers" tab. The quickest way to add large quantities of taxa to a list requires changing the display mode to "Batch Linking", which displays a table view of the specimens. The user can select the vouchers one by one or click the box in the top left corner of the list to Select all (Fig. 23). At the bottom of the page, there are two boxes that offer options for adding these taxa to the list (Fig. 23). The first option "Add name using current taxonomy" is recommended to ensure the taxonomy is consistent with the taxonomic thesaurus. The second option "Add names without linking vouchers" allows you to choose to upload just names or both names and vouchered specimens (Fig. 23). Note that this method only batch uploads ~200 taxa at a time so repeat these steps as necessary to complete your checklist. Click "Submit Vouchers" to link the voucher specimens to your checklist.

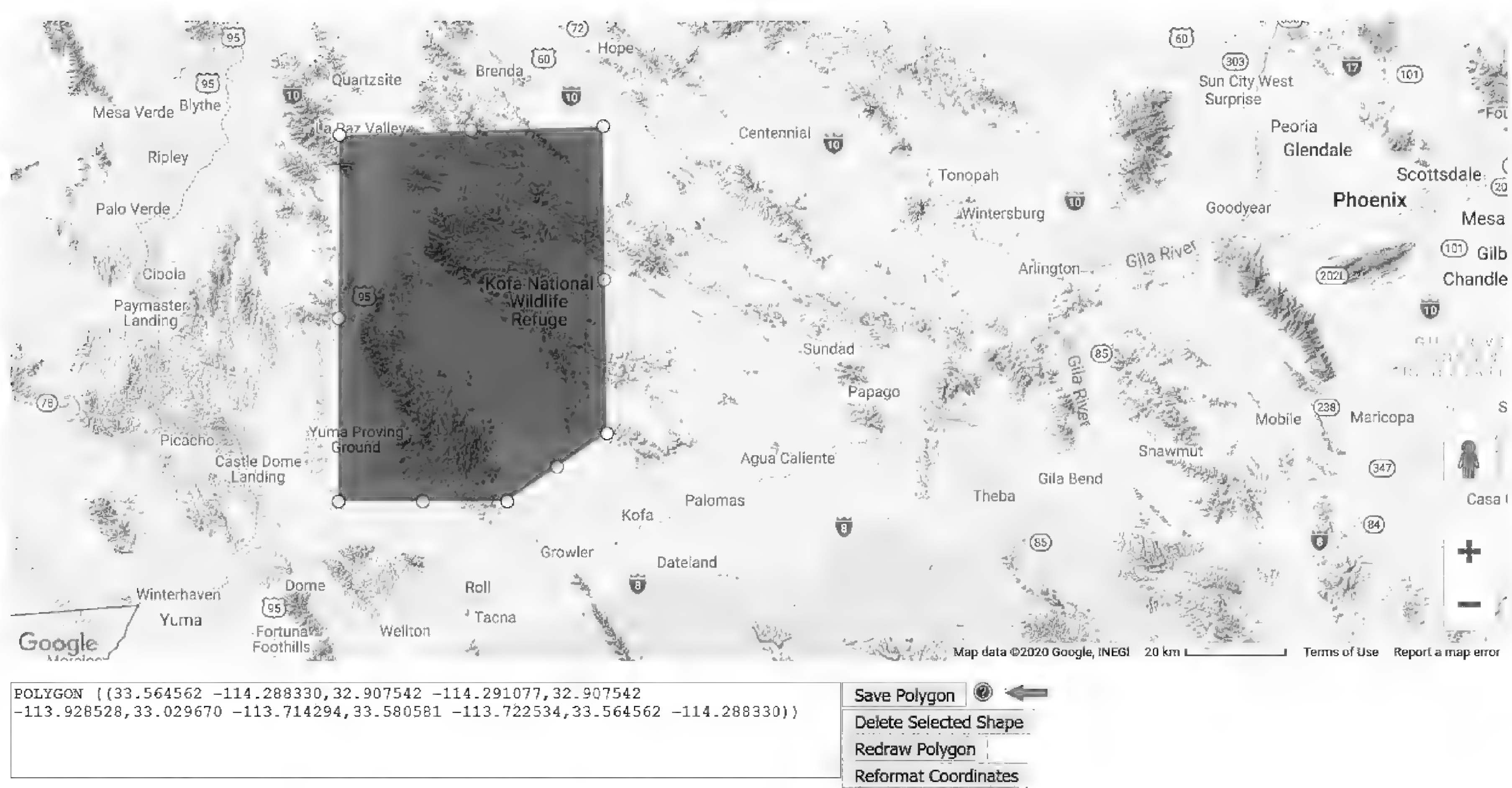
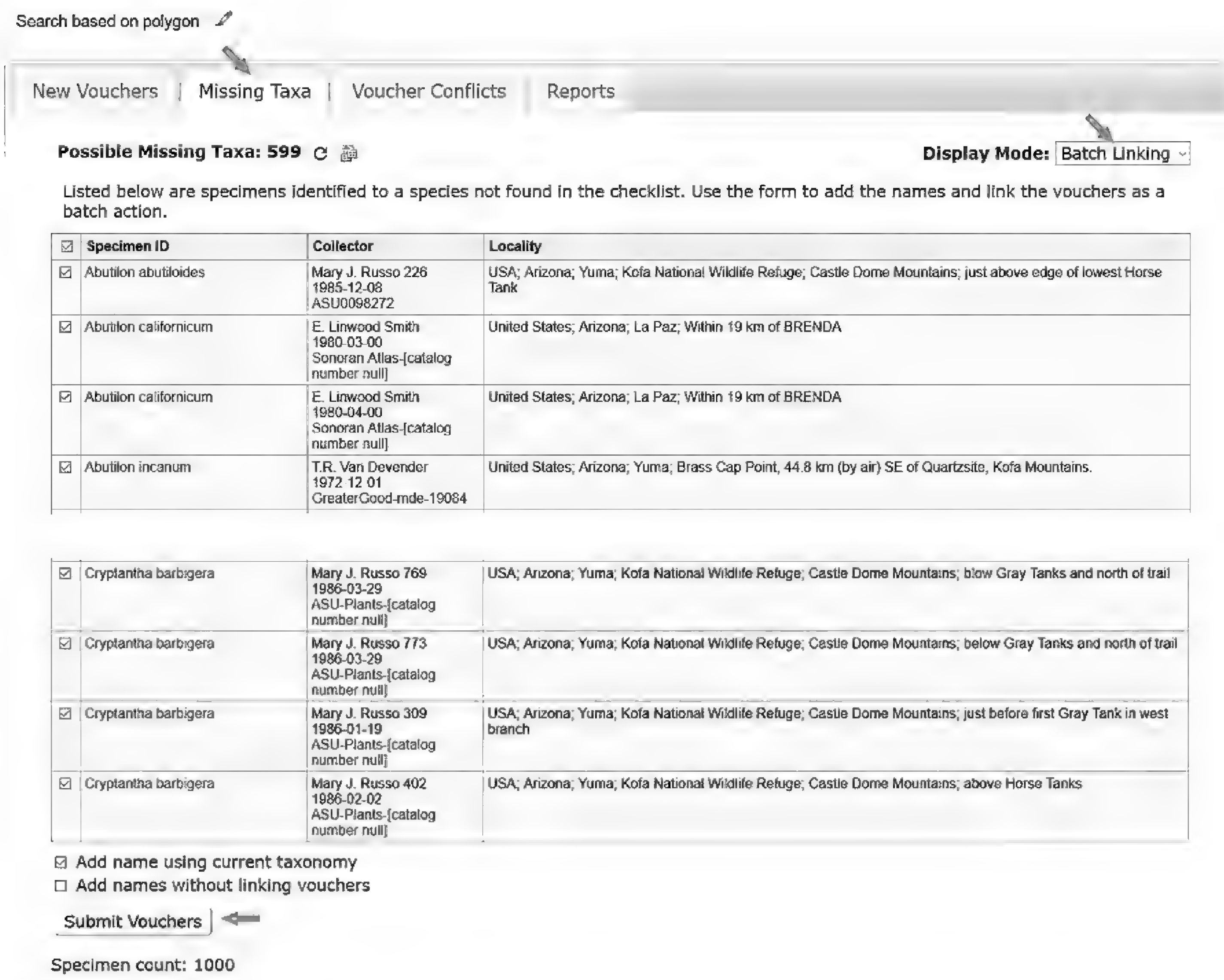



**Figure 22.** Map view page for creating a polygon using the Manage Vouchers Tool. Red arrow indicates the "Save Polygon" button to proceed to save your coordinates for the checklist.




| ☑ | Specimen ID | Collector | Locality |
|---|---|---|---|
| ☑ | Abutilon abutiloides | Mary J. Russo 226 1985-12-08 ASU0098272 | USA; Arizona; Yuma; Kofa National Wildlife Refuge; Castle Dome Mountains; just above edge of lowest Horse Tank |
| ☑ | Abutilon californicum | E. Linwood Smith 1980-03-00 Sonoran Atlas-[catalog number null] | United States; Arizona; La Paz; Within 19 km of BRENDA |
| ☑ | Abutilon californicum | E. Linwood Smith 1980-04-00 Sonoran Atlas-[catalog number null] | United States; Arizona; La Paz; Within 19 km of BRENDA |
| ☑ | Abutilon incanum | T.R. Van Devender 1972 12 01 GreaterGood-mde-19084 | United States; Arizona; Yuma; Brass Cap Point, 44.8 km (by air) SE of Quartzsite, Kofa Mountains. |
| ☑ | Cryptantha barbigera | Mary J. Russo 769 1986-03-29 ASU-Plants-[catalog number null] | USA; Arizona; Yuma; Kofa National Wildlife Refuge; Castle Dome Mountains; blow Gray Tanks and north of trail |
| ☑ | Cryptantha barbigera | Mary J. Russo 773 1986-03-29 ASU-Plants-[catalog number null] | USA; Arizona; Yuma; Kofa National Wildlife Refuge; Castle Dome Mountains; below Gray Tanks and north of trail |
| ☑ | Cryptantha barbigera | Mary J. Russo 309 1986-01-19 ASU-Plants-[catalog number null] | USA; Arizona; Yuma; Kofa National Wildlife Refuge; Castle Dome Mountains; just before first Gray Tank in west branch |
| ☑ | Cryptantha barbigera | Mary J. Russo 402 1986-02-02 ASU-Plants-[catalog number null] | USA; Arizona; Yuma; Kofa National Wildlife Refuge; Castle Dome Mountains; above Horse Tanks |



**Figure 23.** Table view of potential vouchers for Missing Taxa. **Above**: Four specimens at top of the list potential vouchers. First red arrow indicates the "Missing Taxa" tab. Second red arrow indicates how to switch the display mode to "Batch Linking" so you can select a large quantity of vouchers all at once to save to your list. The display (above and below) lists taxon names and potential voucher specimens for those names. **Below**: Four specimens at bottom of the list with "Add name using current taxonomy" selected. "Submit vouchers" marked with Red arrow. Individual specimens may be selected by checking the box on the left or as in this case all specimens have been selected by checking the box at the top of the column to the left of "Specimen ID".

## CREATING A CHECKLIST BASED ON A COLLECTOR

So far, the checklists we have created have all been based on geography. It is also possible to use "Collector" as your principal criterion. To demonstrate this feature, we made a saved checklist, "W. H. Emory", of species collected by William H. Emory. Emory was a military officer and topographical engineer of the 19th century. In 1846, during the war between Mexico and the United States, he was assigned to a military expedition to what is now New Mexico, Arizona, and California (Emory 1848; Norris et al. 1998). He later supervised the survey of the boundary between these countries. Considering the many responsibilities Emory had (e.g., establishing coordinates by astronomical observations, mapping, planning and supervising the construction of a fort, participating in military activities), it seems likely that he was aided in his plant collecting by his collaborators. In any case, the specimens generally appear with his name. His plant specimens were often "new to science" and many were later used as type specimens by botanists such as John Torrey and Asa Gray.

We began adding a single name to the "W. H. Emory" checklist, *Quercus emoryi* Torr. We searched the SEINet database for a specimen of *Q. emoryi* collected by Emory, which turned out to be the type specimen at the New York Botanical Garden herbarium (NY) displayed in the Occurrence Records tab. We clicked on "Full Record Details" and came to a new window with label information and a photo of the specimen (Fig. 24). Locating the three

tabs at the top of the page, we switched to the "Linked Resources" tab, which prompted a new page, "Species Checklist Relationships" with a green + on the right. Clicking the + displayed "New Voucher Assignment" (Fig. 25) with a dropdown menu of potential checklists. We chose the "W. H. Emory" checklist and clicked on the "Add Voucher" tab. The next screen allows for general editing and voucher administration and can be ignored for now.

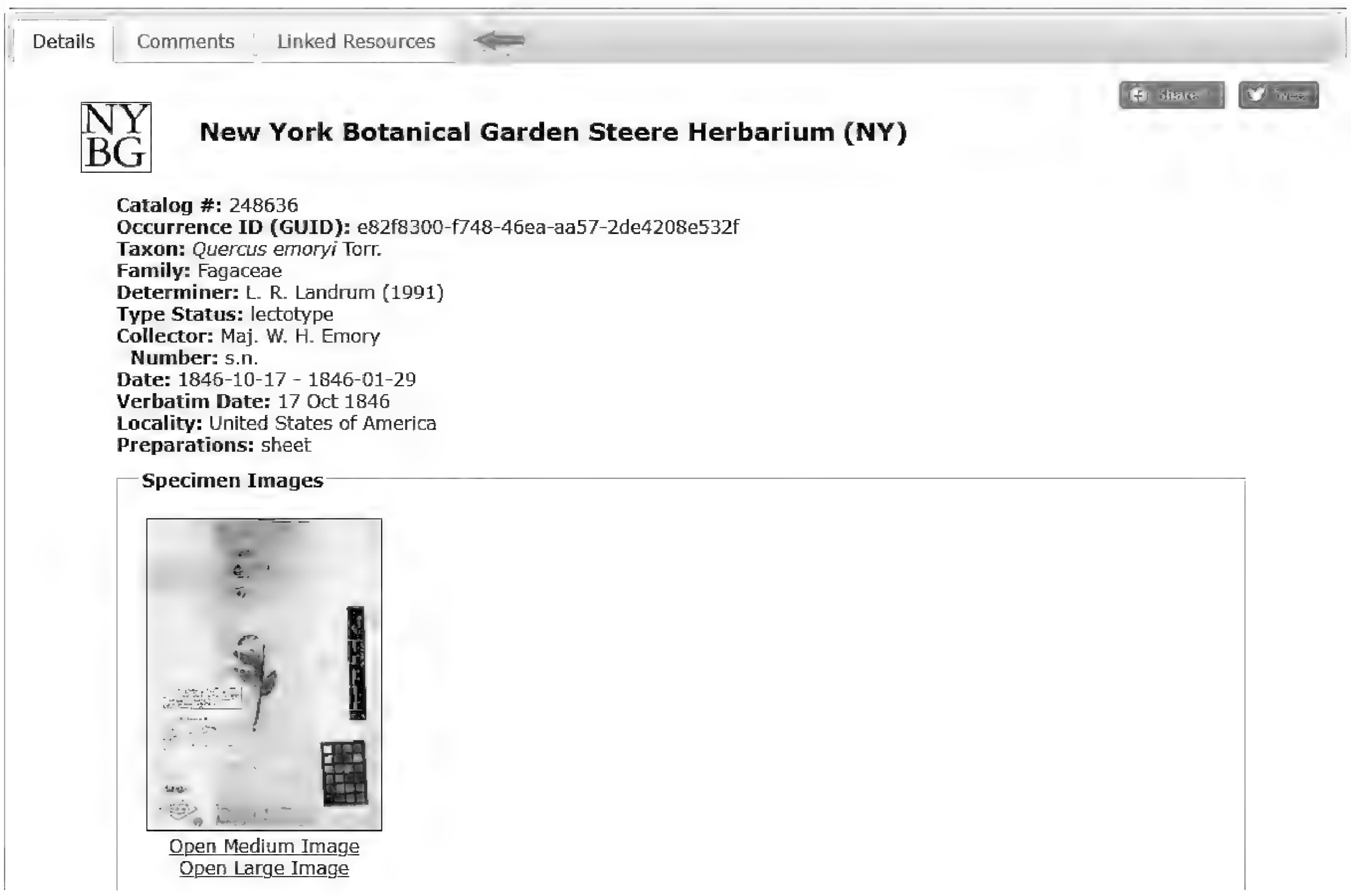



**Figure 24.** Occurence record of Emory's collection of *Quercus emoryi,* the type specimen at NY. The arrow indicates the Linked Recources Tab.

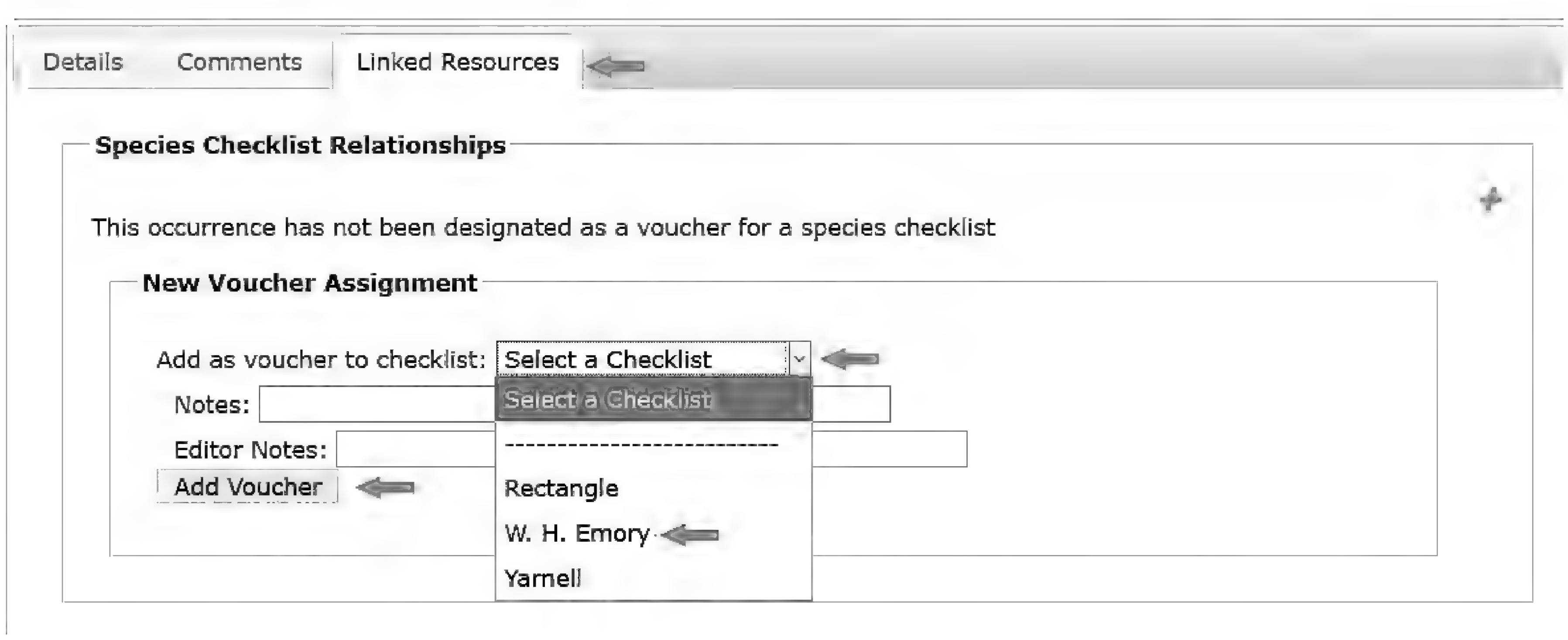



**Figure 25.** Linked Resources Page. This is the third tab accessible from the original Occurrence record (see Fig. 24). Click the green + symbol to access the "New Voucher Assignment" box. Click "Select Checklist" to extend dropdown menu options and select your checklist of choice ("W. H. Emory" in this case). Click "Add Voucher" button to proceed.

You can also add taxa as a group to a checklist as we have done with the geographic checklists. In this case we used the "Manage Linked Voucher" option (Fig. 18, red 2) as described above. In the "Edit Search Statement" we filled in the "collector" box with "W. H. Emory" (Fig. 26). Next, we used the "Missing Taxa" tab and Batch Linking option in Display Mode (Fig. 22). We found that collections of several people named Emory appeared. It is possible to scan the list and select only specimens with W. H. Emory as collector. However, to expedite the process we modified the search statement by returning to the "Manage Linked Vouchers" option and including the name of a state (e.g., New Mexico) in the Search Statement. Modifying the search statement excluded most specimens made by collectors other than W. H. Emory. We repeated this process with other states that W. H. Emory was known to visit and quickly found numerous collections of interest. A portion of the list with voucher specimens listed is shown in Fig. 27.

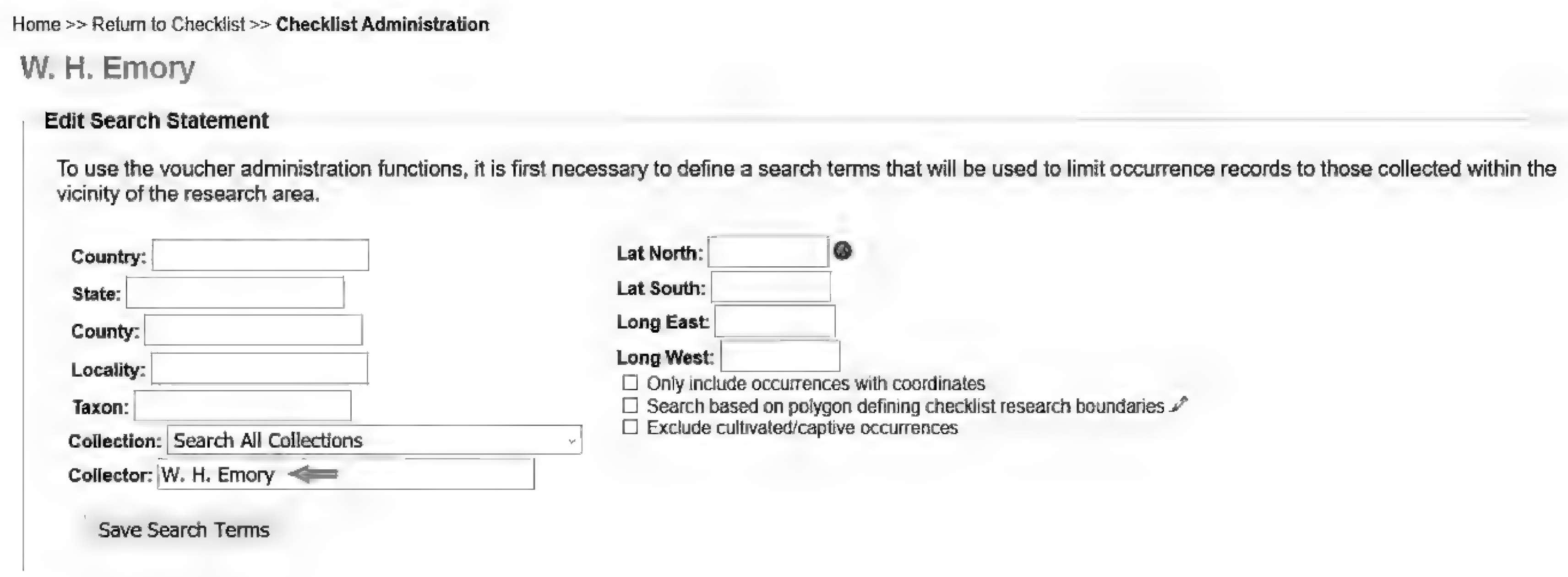



**Figure 26.** Search Statement with "W. H. Emory" as the only criterion in the Collector box. By adding another criterion, for example New Mexico in the State box it is possible to narrow the search.


**Figure 27.** A portion of the H. W. Emory checklist with vouchers displayed.

Notice in Fig. 26 that the Search Statement does not include an option to indicate dates, elevation, or collector number. These can all be included by producing a checklist (Fig. 8) from a Specimen Search in Search Collections (Fig. 3). Using option 3 in Fig. 8, a CSV file

can be downloaded, which in turn can be used to Batch Upload the names to a saved checklist as discussed above (Figs. 18 & 19).

## CONCLUSION

The SEINet database combined with the Symbiota portals that deliver its data provide unparalleled accessibility to a network of herbarium specimens and observations at the click of a button. You have been introduced to the utility of checklists, for example, generating a mini field-guide based on a map search, using an interactive key for identifying taxa, researching historical collections, or producing a list of taxa as a study aid for you or your students. Now, you have the knowledge of how to make, save, and edit your own private checklist, or share it as a public checklist across Symbiota platforms. Our examples included geographically based and collector-based checklists. Another kind of checklist is introduced by Lafferty and Landrum (2021, in this volume). They developed a new program, NEARBY, that makes use of three Symbiota databases – SEINet, NEOTROPICAL, and CNALH (lichens). It constructs checklists of taxa that grow near a primary species (e.g., the 100 most commonly collected plants near *Pinus ponderosa* in Arizona) and provides tools for analyzing the acquired data.

The value of the collaborative effort in building databases and the power of shared data is enormous. What surprising discoveries will be uncovered using Symbiota databases and portals? As the amount of digitized specimen data from herbaria around the world continues to grow, the opportunities for scientific discovery and educating ourselves and others abound.

## ACKNOWLEDGEMENTS

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# NEARBY, a Computer Program for Phytogeographic Analysis Using Georeferenced Specimen Data

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**ABSTRACT:** We present a computer program, NEARBY, that uses databases of georeferenced specimens to explore plant and lichen distributions and co-occurrences. NEARBY utilizes three SYMBIOTA databases: SEINet (mainly vascular plants of North America), NEOTROPICAL (mainly vascular plants of neotropical and temperate South America), and CNALH (lichens, mainly of the western hemisphere). A Primary species is entered into the program and a geographic area is defined. Parameters are chosen that limit the search for specimens of Secondary species that have been collected near the Primary species. The output consists of: a summary of the input data and how it was modified for the search; a list of the most commonly found Secondary species that occur with the Primary species in the defined area; and additional data and links to images for each species. These data can be manipulated in various ways or copied into another program for analysis. NEARBY includes a map option that allows the user to compare distributions of the Primary and Secondary species. An example of a search is discussed in detail and case studies that illustrate the use of the program are provided. An appendix describing the program function is provided.

## INTRODUCTION

The distribution of organisms across landscapes, continents, and the globe have long been an interest of biologists, including Humboldt and Bonpland (1807; English translation 2009), Hooker (1853), and Darwin (1859; reprint 1985). Hooker emphasized how difficult a subject plant geography can be in his introduction to the *Flora of Novae-Zelandiae*:

> *"Of all the branches of botany there is none whose elucidation demands so much preparatory study, or so extensive an acquaintance with plants and their affinities, as that of the geographic distribution."*

In Hooker's case, it meant traveling by sailing ship around the southern end of the world exploring southern South America, New Zealand, Tasmania, Australia, and various small and isolated islands. Until recently, discovering where plants grow and with which other species they are found involved much fieldwork and/or many visits to herbaria. It is a slow process and might require a great deal of work to obtain just a few plant distributions that can then be compared. With the recent advances in specimen databasing and georeferencing, preliminary distribution studies for many parts of the world may be made in minutes, thanks to the large databases of herbarium specimens (and museum records for other organisms) that have recently been amassed (e.g., GBIF, CRIA). We here present a computer program, NEARBY

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(https://serv.biokic.asu.edu/dlafferty/Nearby/index.php), that uses three SYMBIOTA databases and allows one to rapidly discover what species of plants and/or lichens grow near one another and simultaneously compare the distributions of several species.

We previously presented two programs (PROXIMITY and CORRELATION) that allow a user to discover plant associations (vegetation types or continua) based on a list of plants, chosen because they are known to be dominant or conspicuous species in vegetation (Landrum & Lafferty 2015). The resulting associations depend on the list of plants one chooses in the operation of the program. With NEARBY the user starts with a single species (the Primary species) and then searches one or more databases for other species (the Secondary species) that grow near the Primary species using coordinate data (Figs. 1–3).

For this report we are using three databases established using the SYMBIOTA software package (Gries et al. 2014): the **SEINet** database (http://symbiota.org/docs/seinet/) of vascular plant herbarium specimens, with ca. 17.9 million specimen records, mainly from North America; the **NEOTROPICAL** database, mainly of vascular plants of neotropical and temperate South America (https://serv.biokic.asu.edu/neotrop/plantae/index.php) with ca. 3.6 million records; and the **CNALH** database of the Consortium of North American Lichen Herbaria (https://lichenportal.org/cnalh/) with ca. 2.6 million records, of lichens only, mainly of the Western Hemisphere. All databases are actively growing and these numbers are estimates made in August 2020. All use a combination of “live data” (which can be updated immediately by an administrator) and “snapshot data” (a copied database that is infrequently updated). The user should remember that some “snapshot data” may be weeks or months old.

The purpose of NEARBY is to quickly explore phytogeographic data. Fieldwork, including observations, collections, and systematic sampling of vegetation, will normally be a more complete and accurate way of sampling vegetation than databases, but much more time consuming. As a preliminary investigation of plant associations and plant geography we believe NEARBY will be quite valuable. In some cases, such as broad surveys, relying on databases that already exist will be the best strategy. NEARBY has the advantage of being able to use databases for different groups of organisms (e.g., lichens and vascular plants). We hope that insects, vertebrates, fungi, and bryophytes may eventually be added.

We have previously discussed the disadvantages and advantages of using databases of herbarium specimens for phytogeographic/phytosociological studies (Landrum & Lafferty 2015). In summary, the main disadvantages are that databases are never perfect: the specimens may be misidentified, or they may be georeferenced incorrectly or with a low degree of precision. These imperfections must be kept in mind. But we believe the large majority of data to be fairly accurate and thus those data will tend to “overwhelm” inaccurate data. The main advantages are that 1) the data we use already exist for millions of plant and lichen specimens (and are potentially available from other natural history collection databases) and only need to be analyzed—there is no new fieldwork required; 2) herbarium specimens are permanent vouchers of the existence of a species of plant or lichen at a specific place at a particular time, and therefore can be checked if there are doubts about their correct identification or georeferencing; and 3) herbarium specimens have been collected mainly for floristic, taxonomic, and ecological studies. Thus, the data they provide in databases, which in turn are used by NEARBY, are relatively unbiased in a phytogeographic study.

## USING NEARBY

We will next briefly describe how to use NEARBY by "walking the reader through" a sample case. In the example we have selected *Pinus ponderosa* as the Primary species and the region of interest as Arizona.

**Primary Species**. The opening screen of NEARBY is where the user sets the parameters of a search. The upper half of the screen is shown in Fig. 1. The first step is to select a Primary species, in this case we will use *Pinus ponderosa*. Occasionally a species may be listed under more than one name in the database. The names *Rhus aromatica* and *R. trilobata* both appear in the SEINet database and we consider them to be synonyms and accept *R. aromatica* as the correct name. So, if it was a Primary species, we would list both names separated by commas, (*Rhus aromatica,Rhus trilobata*), with the accepted name first.

**Companion Species**. If the name of an optional Companion species is entered, then only Primary species specimens with a Companion species close by (defined by the Distance parameter discussed below) will be included. In other words, the original list of Primary species specimens is reduced to those that have a Companion species specimen close by. For instance, one might want to know what plant species grow near the Primary species *Pinus ponderosa* and its frequent associate (or companion) *Pseudotsuga menziesii.* As with Primary species, Companion species can have synonyms, separated by commas. In this example we will not use a Companion species.

**Selecting States or Countries**. There is a map of the American continents and associated islands. If you want to select particular states of the United States or Mexico, or provinces of Canada there are boxes below the map to check to toggle this option off or on. If these are not checked you will only be able to select these as whole countries. The larger Caribbean islands and countries (e.g., Cuba, Dominican Republic) can be selected. Individual small islands cannot be checked individually but groups of islands (e.g., Lesser Antilles) can be. Using the map, one clicks on the states or countries to toggle them on or off. Searches for Primary, Companion, and Secondary species specimens will be limited to the entities selected. If no states of countries are selected, the entire database will be used. It is possible to select states in one country (e.g., those of the United States bordering Mexico) and a whole country such as Mexico for a search. In this example we will check "Show US States" and select only Arizona.

**Search Limits**. There are several options that affect the scope of the search. In this example we will accept the default settings but will briefly discuss the options.

> ***Distance***: This value indicates how close specimens must be to be considered "nearby". The default is 100 m, which defines a square 200 m on a side with the Primary at its center. Note that a Companion species or Secondary species specimen is considered "nearby" if it is within this square. Distance is not calculated radially, as that calculation would add significantly to server load. For the purposes of this program, square plots are just as appropriate. If in a search few Secondary species are found, the distance parameter can be increased.

***Cull specimens if more than***: Points (defined by coordinates) with numerous specimens georeferenced to them are suspect—the specimens have probably been georeferenced as a group, perhaps mechanically by being the middle of a city, state, or country. NEARBY allows the operator to eliminate these suspect specimens by setting a cull number: when the number of specimens georeferenced to a point exceeds this number, the specimens are excluded from the search. The default cull number is 50, but it can be set to other numbers up to 100. The program will never accept locations with more than 100 specimens georeferenced to a single point because that would cause it run too slowly. The specimens that pass this test (apparently not mechanically georeferenced) are then utilized.

***Limit***: This number sets an upper limit on the number of Primary species specimens included in the search. The default is 1000 and this number is rarely reached in our experience. Limiting to a lower number may produce a faster result in some cases. If the program does not produce a result in three minutes, lowering the Limit downward may help. When this limit is set to a number, for example 500, and the full number of Primary specimens is larger, for example 2000, the full list of Primary specimens is first obtained, in this case 2000, and randomized.

***Truncate list of species at***: Once all the Secondary species specimens are found for all the Primary species specimens, the data are sorted by **% *Primaries near this Secondary*** (this term defined below). The default is to consider only the most commonly found 50 species and truncate the list at that level. But numbers other than 50 may be used. This is just a way to keep the list reasonably short. It also reduces the calculation time somewhat. It is common for multiple species to have exactly the same percentage value, so increasing the list size to make sure you have all the species up to a certain value may be useful.

***Don't allow Primary species specimens near other Primary specimens:*** If two Primary species specimens have exactly the same coordinates they are always counted just once. In addition, by leaving this default option on, if two Primary species specimens are close enough together to be considered as Secondaries of one another, only one is accepted. When Primary species specimens are few, it may be beneficial to turn off this option. When a genus name is chosen as the Primary we find that it is best to turn this option off, because species of the same genus are often collected together.

***Stop after obtaining Primary species data***: If this is checked, the program will stop after determining the number of Primary species specimens found in the region, or after determining the number limited by Companion species if it is included. This is often a good preliminary step to quickly check for the number of Primary species specimens in the selected area. When searching with just a Primary species it is probably best to find at least 100 individuals. Searches with 200 to 1000 are better. When searching for a Primary and a Companion species together, lower numbers are acceptable. The best way to increase the numbers is to include a wider search area by adding more states or countries.


**Figure 1**. Upper half of opening NEARBY screen. “Instructions” near top leads to help page on using NEARBY at this stage. In this case the user has chosen *Pinus ponderosa* as the Primary species. The option to “Show US States” has been toggled on and Arizona has been selected as the search area.

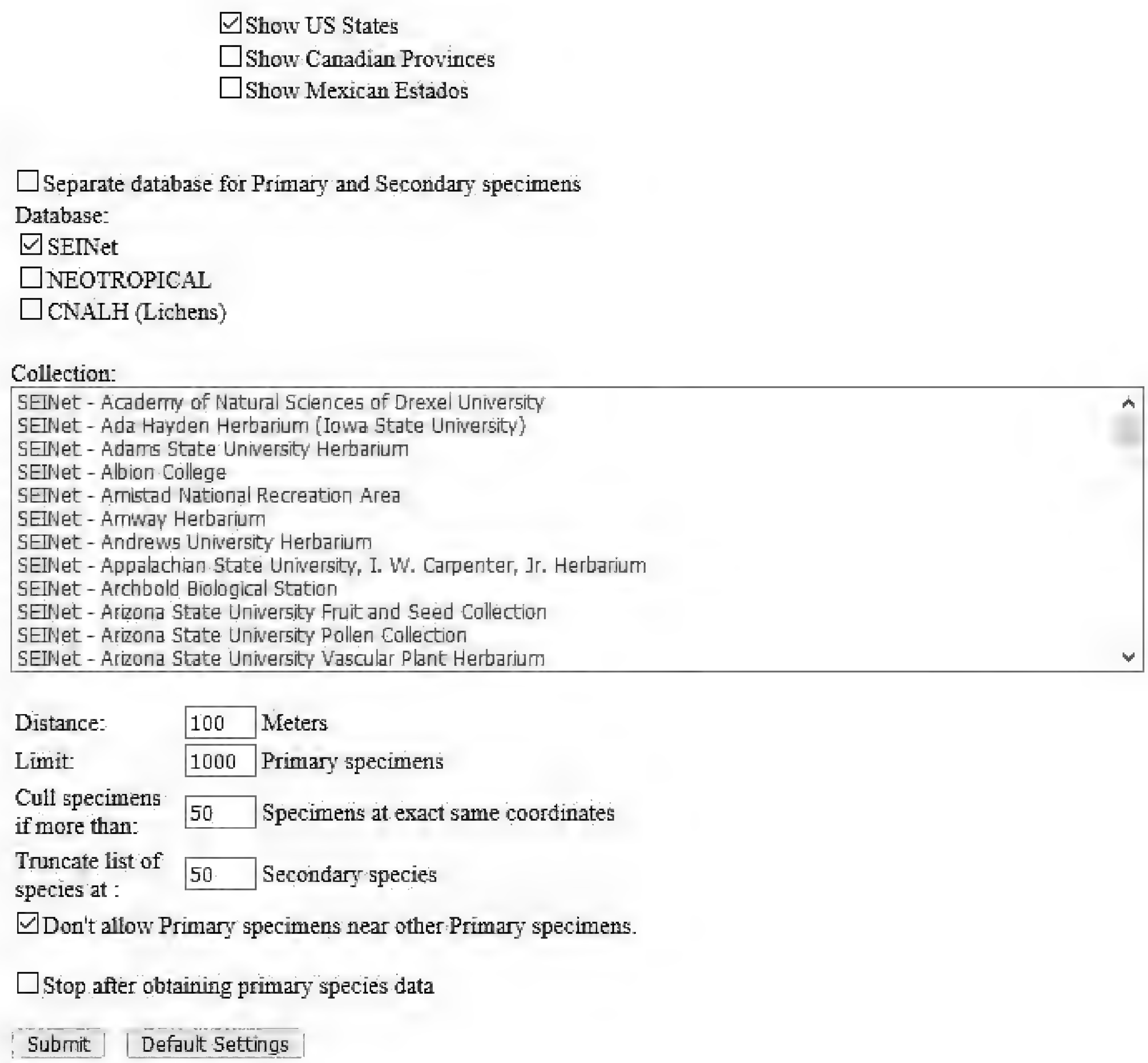


**Figure 2.** Screenshot of lower half of first screen of NEARBY with default parameters. Only the SEINet data base has been selected. See text for further explanation of how the parameters affect a search.

**Output Display**. Once all the numbers have been calculated, a table is displayed. A small portion of the table for this example is shown in Fig. 3. The table can be highlighted and copied into Excel, or similar program, for later reference if desired.

The output is divided into ten columns explained below. Clicking on the header for each column will sort the table by that column (e.g., by family or median elevation). Clicking on a scientific name will open a new page in SYMBIOTA showing details on that species. Clicking on “Show Images” at the top will add a thumbnail image of each Secondary species. Mousing over that thumbnail will pop-up a larger image and clicking on the thumbnail will open an even larger image in a separate window.

At the top of the page information about the search is given (e.g., the parameters used). In this case 276 specimens were found, but these were reduced to 222 “usable” specimen localities. Reasons for reducing specimens might be that two or more were found with exactly the same coordinates or were close enough to be considered Secondaries of each other or were found at a locality deemed to be mechanically georeferenced as a group. All numbers in the calculations below refer to “usable” specimens only.

**Map**: Just above the upper left-hand corner of the table is the word "Map." By clicking on Map, a dot map of the Primary species is presented in a separate window. On the left side is a list of the Secondary species and by clicking on each name the species distribution is shown as dots, each with a distinctive color. This option will be discussed in more detail below.

**Total Secondary Count**: The total number of this Secondary species specimens collected and georeferenced in the defined region (e.g., 533 *Quercus gambelii* in Arizona).

**Secondaries near this Primary**: The number of georeferenced specimens of this species collected near a Primary species specimen (e.g., 50 *Quercus gambelii* were near a *Pinus ponderosa*).

**% Secondaries near this Primary**: The percent of georeferenced specimens of this species that were collected near a Primary species specimen, (e.g. 50/533 = 9.3% of the *Quercus gambelii* were collected near a *Pinus ponderosa*). When the number of Primaries (set by the "**Limit**") is less than the total in the selected region, then this percentage of Secondary species specimens in the defined area is adjusted to approximately compensate for the reduced sample. None of the other results need this adjustment.

**Primaries near this Secondary**: The number of Primary species specimens that have at least one of this Secondary species collected nearby (e.g. 39 of the 222 *Pinus ponderosa* specimens had a *Quercus gambelii* collected nearby).

**%Primaries near this Secondary**: The percent of the total Primary species specimens that have at least one specimen of this Secondary collected nearby (e.g. 39/222 = 17.5% of the *Pinus ponderosa* had at least one *Quercus gambelii* collected nearby).

**Scientific Name**: Genus and specific epithet for the Secondary species, including all specimens identified as subspecies and varieties. Synonyms are not included for Secondary species. NEARBY uses the names as they appear in the databases, so Secondary species may appear under more than one name that the user considers synonyms or even common misspellings.

**Family**: Plant family name for each species.

**Median Elevation**: Median Elevation of the listed Secondary species. Median is determined by all the "usable" specimens in the defined region that have elevation data. Those specimens culled because of identical coordinates are not included.

The last columns are ***Median Latitude*** and ***Median Longitude*** of the listed Secondary species. These may prove useful in a broad geographic search.

Primary: Pinus ponderosa
States: Arizona
Databases: SEINet
Meters: 100
Maximum specimens same coordinates: 50
Nearby primaries removed
Primary Limit: 1000
Found 276 total Pinus ponderosa

Filtered for usable locations, retaining 222 Pinus ponderosa localities
Median Elevation = 2134 meters
Median Lat = 34.384, Median Long = -111.114
Explanation of Output
Start over
Show Images
Map

| Total Secondary Count | Secondaries near this Primary | % Secondaries near this Primary* | Primaries near this Secondary | % Primaries near this Secondary | Scientific Name | Family | Median Elevation | Median Latitude | Median Longitude |
|---|---|---|---|---|---|---|---|---|---|
| 533 | 50 | 9.3% | 39 | 17.5% | Quercus gambelii | Fagaceae | 1981 | 34.880 | -111.449 |
| 256 | 44 | 17.1% | 37 | 16.6% | Pseudotsuga menziesii | Pinaceae | 2286 | 34.407 | -110.892 |
| 1214 | 37 | 3% | 32 | 14.4% | Erigeron divergens | Asteraceae | 1760 | 34.486 | -111.467 |
| 101 | 33 | 32.6% | 31 | 13.9% | Pinus strobiformis | Pinaceae | 2560 | 32.696 | -110.723 |
| 389 | 36 | 9.2% | 30 | 13.5% | Ceanothus fendleri | Rhamnaceae | 2133 | 34.321 | -111.022 |
| 163 | 28 | 17.1% | 27 | 12.1% | Abies concolor | Pinaceae | 2316 | 34.398 | -110.982 |
| 847 | 36 | 4.2% | 26 | 11.7% | Elymus elymoides | Poaceae | 1830 | 34.711 | -111.517 |
| 400 | 34 | 8.5% | 25 | 11.2% | Juniperus deppeana | Cupressaceae | 1700 | 33.394 | -110.875 |
| 916 | 29 | 3.1% | 25 | 11.2% | Poa fendleriana | Poaceae | 1798 | 34.921 | -111.677 |
| 148 | 29 | 19.5% | 24 | 10.8% | Arceuthobium vaginatum | Santalaceae | 2226 | 34.170 | -110.988 |

**Figure 3. Output of a query of *Pinus ponderosa* in Arizona.** "Explanation of Output" near top leads to help page on using NEARBY at this stage. In this case the Primary species is *Pinus ponderosa* and the search area Arizona. The area around each Primary species specimen is defined by "Meters: 100" and refers to the distance from the Primary species specimens to the edges of a square sampling area. Each Primary species specimen defines a square 200 m on a side with the specimen at the center. Any locality with more than 50 specimens with exactly the same coordinates has been eliminated. When two Primaries are close enough to be considered Secondaries of each other, one is removed. After filtering for these parameters 222 "usable" Primaries were found. Only the 10 Secondary species with the highest "**% Primaries near this Secondary**" are shown. The default is set at 50 species, but the number can be changed.

By sorting on **Family** one can produce a systematic list of the plant species most likely to be encountered in a *P. ponderosa* forest—a mini-flora. And it can easily be illustrated by clicking on "**Show Images**."

By sorting on **% Primaries near this Secondary** (the default sorting) we order the list by the most frequently associated species. We might want to choose one of these as a companion species to run another query that is more focused on a particular vegetation type.

By sorting on **% Secondaries near this Primary** we order the Secondary species as to how consistently they occur with the Primary species. If the total number of specimens of a Secondary species is small (e.g., less than 10), the percentage may be high, but probably of limited significance.

By sorting on **Median Elevation,** we may see how the Secondary species change with elevation. This can be interesting in areas with significant differences in elevation.

No matter how the Secondary species names are sorted they are reproduced as a list with family names at the end of the output file. They can easily be copied and pasted into another program such as Excel or Access for further analysis.

## CASE STUDIES

We here present a few sample uses of NEARBY. These are not meant to be definitive studies but only examples of what might be done.

**Secondary species commonly growing with a Primary.** The objective of this example was to compile a list of the plants commonly found with *Kalmia latifolia* (Ericaceae), which was used as the Primary species. The search was made in the eastern states of Alabama, Florida, Georgia, Kentucky, Maryland, Mississippi, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. The default settings were used except that a list of 100 Secondary species was obtained instead of 50. In this example 773 "usable" *Kalmia latifolia* specimens were found. The 100 Secondary species found belonged to 50 families, most with one, two, or three species. Cyperaceae and Pinaceae each had four species, and Rosaceae had 6 species. Only Ericaceae had more, with 14 species. If one includes *K. latifolia* itself, which was necessarily present by being the Primary, the number is 15. This is an unusual family distribution and is probably caused by the preference or tolerance of Ericaceae to acid soils. Ten of the species with the highest "**% Primaries near this Secondary**" are listed in Table 1.

**Table 1**. Sample of ten species found with *Kalmia latifolia* in eastern United States. These species had the highest "**% Primaries near this Secondary**".

| % | Species | Family |
|---|---|---|
| 11.5 | *Hamamelis virginiana* | (Hamamelidaceae) |
| 8.5 | *Vaccinium stamineum* | (Ericaceae) |
| 8.4 | *Tsuga canadensis* | (Pinaceae) |
| 7.5 | *Gaylussacia baccata* | (Ericaceae) |
| 6.8 | *Viburnum acerifolium* | (Adoxaceae) |
| 6.8 | *Acer rubrum* | (Sapindaceae) |
| 6.7 | *Vaccinium corymbosum* | (Ericaceae) |
| 6.7 | *Castanea dentata* | (Fagaceae) |
| 6.7 | *Sassafras albidum* | (Lauraceae) |
| 6.7 | *Gaultheria procumbens* | (Ericaceae) |

**Using the Map option.** Here we discuss three studies with NEARBY that use the map option. In Fig. 3, just above the left-hand corner of the table, is the word "Map." By clicking on "Map" a dot map of the Primary species will appear along with a list of Secondary species

ordered as to **“% Primaries near this Secondary”** (e.g., Fig. 4). By clicking on a Secondary species name it also appears in the same map with colored dots. Multiple species can be shown.

***Map study 1***: In this case we used both the SEINet and NEOTROPICAL databases. With a little investigation we found the *Escallonia myrtilloides* (Escalloniaceae) is a common high elevation species with a median elevation of 3250 m. We used it as the Primary species and found that its associated Secondary species mainly have median elevations between 3000 and 3800 m. In this case the distributions are often quite similar (Fig. 4), presumably because their habitat preferences are restricted to a narrow area of high elevations. The most common families among the first 50 associated species were Ericaceae and Melastomataceae with 7 species each.

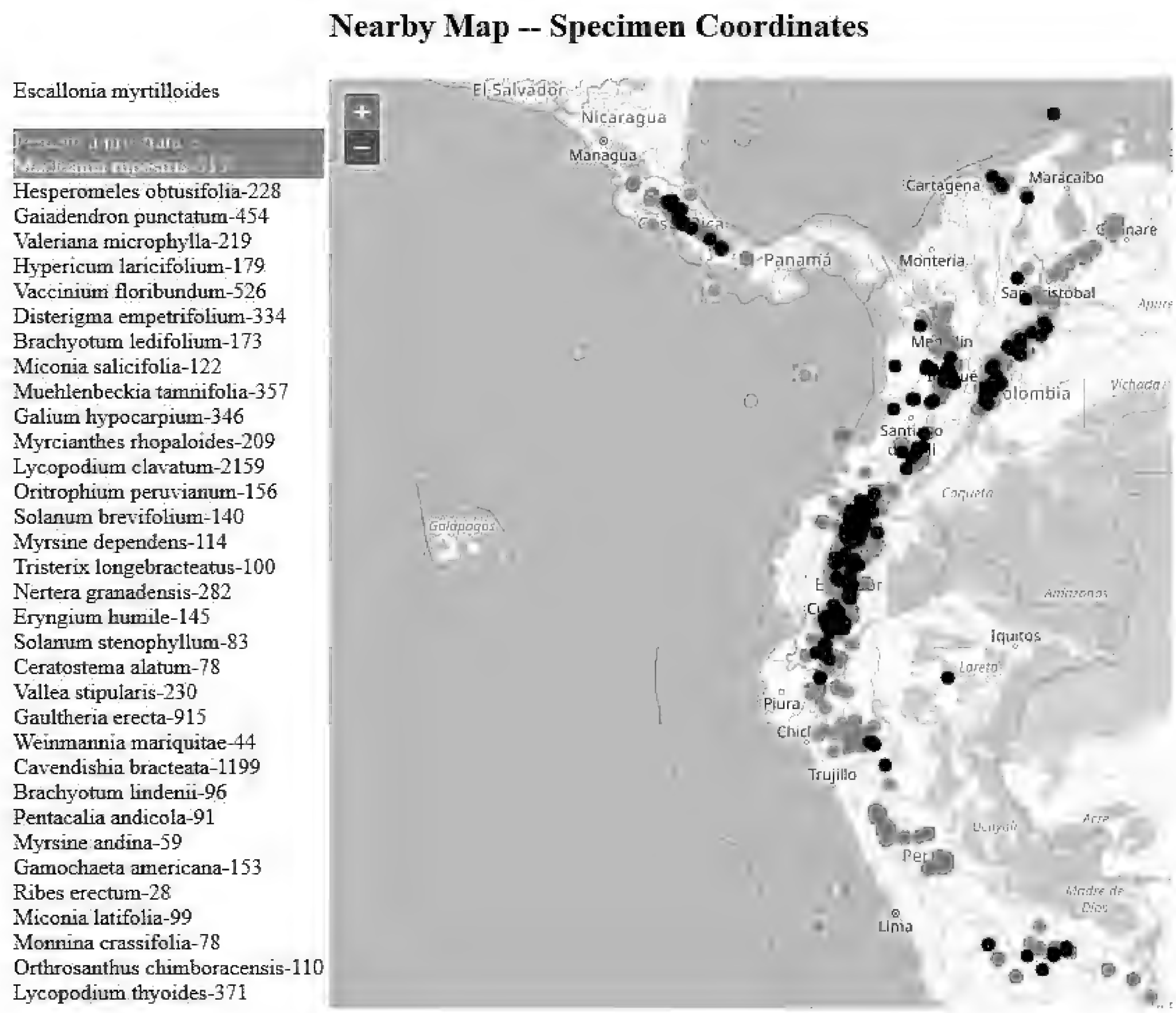


**Figure 4**. Distribution of *Escallonia myrtilloides* (Escalloniaceae; black dots) and its two most common Secondary species, both Ericaceae: *Pernettya prostrata* (light blue dots) and *Macleania rupestris* (pink dots). The few outlying dots in the ocean are examples of georeferencing errors and are a rough indication of the error rate.

***Map study 2***: *Interior Chaparral vegetation in Arizona.* Interior Chaparral (Brown 1994; Brown et al. 2007) is one of the common types of vegetation in Arizona at elevations of about 1000 to 1800 m. The dominant species are shrubs, often with

sclerophyllous leaves, that are adapted to frequent fires by sprouting from roots or stems below ground level. Chaparral is normally found above the Sonoran Desert scrub but lower than Oak Woodland or Ponderosa Pine forest (see Brown 1994 for vegetation types and Brown et al. 2007 for vegetation map). The lines between these kinds of vegetation are often indistinct. Chaparral is often found adjacent to or mixed with Pinyon-Juniper vegetation.

Among the most common dominant or co-dominant species in Interior Chaparral are *Arctostaphylos pringlei* and *A. pungens* (Ericaceae), *Ceanothus greggii* (Rhamnaceae), *Cercocarpus montanus* (Rosaceae), *Eriodictyon angustifolium* (Boraginaceae), *Fendlera rupicola* (Hydrangeaceae), *Garrya flavescens* and *G. wrightii* (Garryaceae), and *Quercus turbinella* (Fagaceae). We have noticed that in different regions chaparral vegetation may have different dominant species and these grow in a variety of associations.

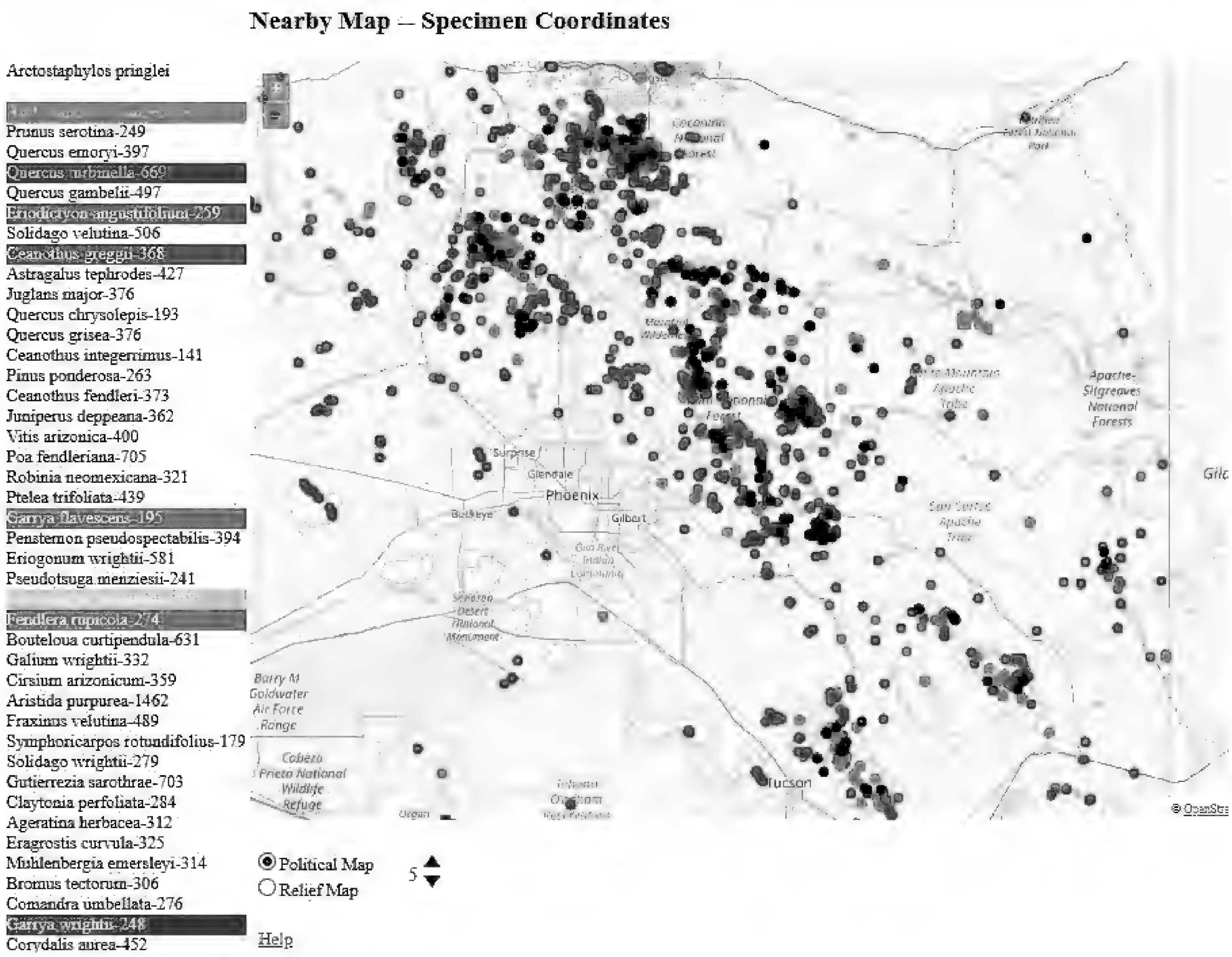


**Figure 5**. Map of nine Interior Chaparral species in central Arizona. The rich Interior Chaparral of central Arizona is a combination of several independent plant species distributions that happen to coincide in that area. Black dots indicate the Primary species, *Arctostaphylos pringlei*, and colored dots are for eight Secondary species. Chaparral species grow beyond central Arizona, but fewer species grow together. See Fig. 6 for an example.

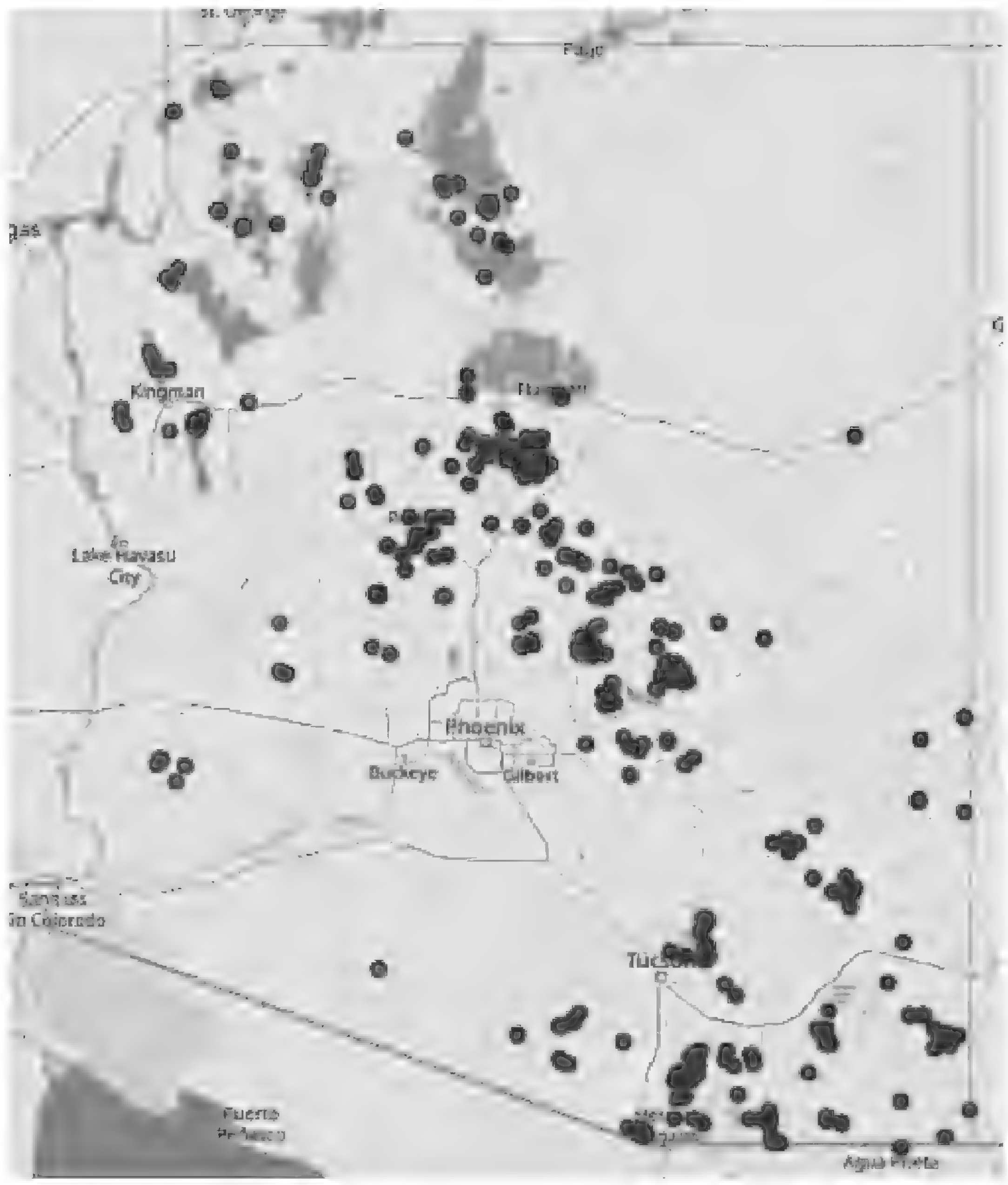


**Figure 6**. *Garrya flavescens* (red dots) extending mainly to north and west and *G. wrightii* (blue dots) mainly extending to east and south.

To investigate the variety of chaparral types in Arizona we started with *Arctostaphylos pringlei* as a Primary and found all the other species mentioned above appeared as Secondaries using the default settings. Using the map option, we mapped all these species on a single map (Fig. 5). All nine species are commonly found together in areas of chaparral between Flagstaff and Tucson. While using the map option as shown in Fig. 5, one can hide the black dots of the Primary species by hovering over its name at the top, and display any combination of species by clicking on the names (a single click toggles the distribution dots on or off). As this is done it becomes clear that the central Arizona highland supports a diverse set of chaparral species that overlap. But individually each species has a distinct distribution that may extend in various directions. For instance, if we reduce the species to *Garrya flavescens* and *G. wrightii* only (Fig. 6), we see that for much of their ranges they do not overlap. Thus, Interior Chaparral is most diverse and complex where the most species overlap in central Arizona. As one travels in any direction from that area, there will be fewer species and chaparral may have a notably different appearance.

***Map study 3***: When doing the chaparral species study we noticed that *Comandra umbellata* was often found with chaparral species. Unknown to many collectors of this species is that it is a hemiparasite. We thought we might find a host-parasite

relationship using NEARBY. Using *C. umbellata* as the Primary species we found seven of the nine chaparral species cited above appear as commonly found Secondaries. We used the map feature to compare its distribution in Arizona (Fig. 7) with the two most commonly found Secondary species (*Ceanothus greggii* and *Arctostaphylos pungens*). *Comandra umbellata* seems to be a common associate of these two chaparral species, but also grows where neither species is found. *Comandra umbellata* may grow with these species because of a similar habitat preference (rocky dry soils) rather than being a host specific hemiparasite of either. Through some literature research we found that *C. umbellata* is widespread in North America and in the Mediterranean region growing well beyond any chaparral species (Nickrent 2016). It is reported to have various hosts (Pielh 1965), so various chaparral and non-chaparral species may be among them.

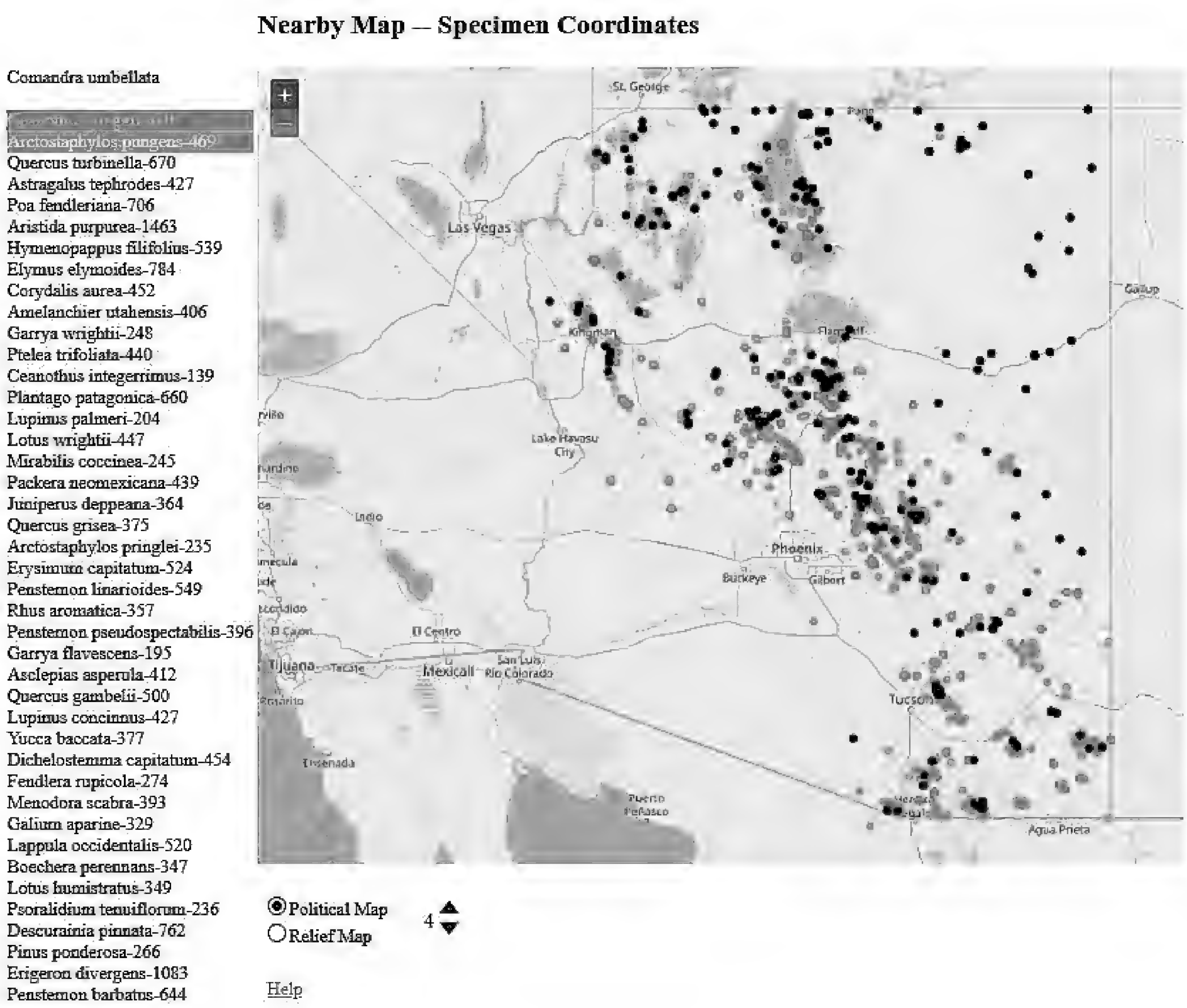


**Figure 7**. Map of *Comandra umbellata* in Arizona (black dots). Seven of the most commonly found Secondary species in left hand column are among the nine chaparral species we used in the study above. The first two Secondary species are represented by colored dots in this map: *Ceanothus greggii* (light blue), *Arctostaphylos pungens* (pink). *Comandra umbellata* seems to be mainly found in chaparral vegetation in Arizona but probably not restricted to it.

**Using different databases for the Primary and Secondaries species.** What vascular plants grow near the lichen *Xanthomendoza fallax* in Arizona and New Mexico? *Xanthomendoza fallax* generally grows on the bark of trees, so we might expect it to be associated with tree species. In this example we used different databases for the Primary and Secondary species. In the opening page of Nearby (Fig. 2), above the list of databases, is a box to check that facilitates doing this. We checked the box and selected the CNALH (Lichens) database for the Primary species and SEINet for the Secondary species. We raised the distance from the Primary to 500 m instead of the default 100 m to obtain a larger sample of Secondaries. We only searched for the first 25 vascular plant species, and among these were four tree species that might provide a substrate for *X. fallax*; they are listed with a map in Fig. 8. The high elevation *Quercus rugosa* indicates oak forests of southeastern Arizona and southwestern New Mexico; and *Fraxinus velutina*, *Acer negundo*, and *Juglans major* are species that grow near oak forest species but also along drainages at lower elevations. So, we can deduce that *X. fallax* probably grows in forests at higher elevations and extends to lower elevations along moist drainages.

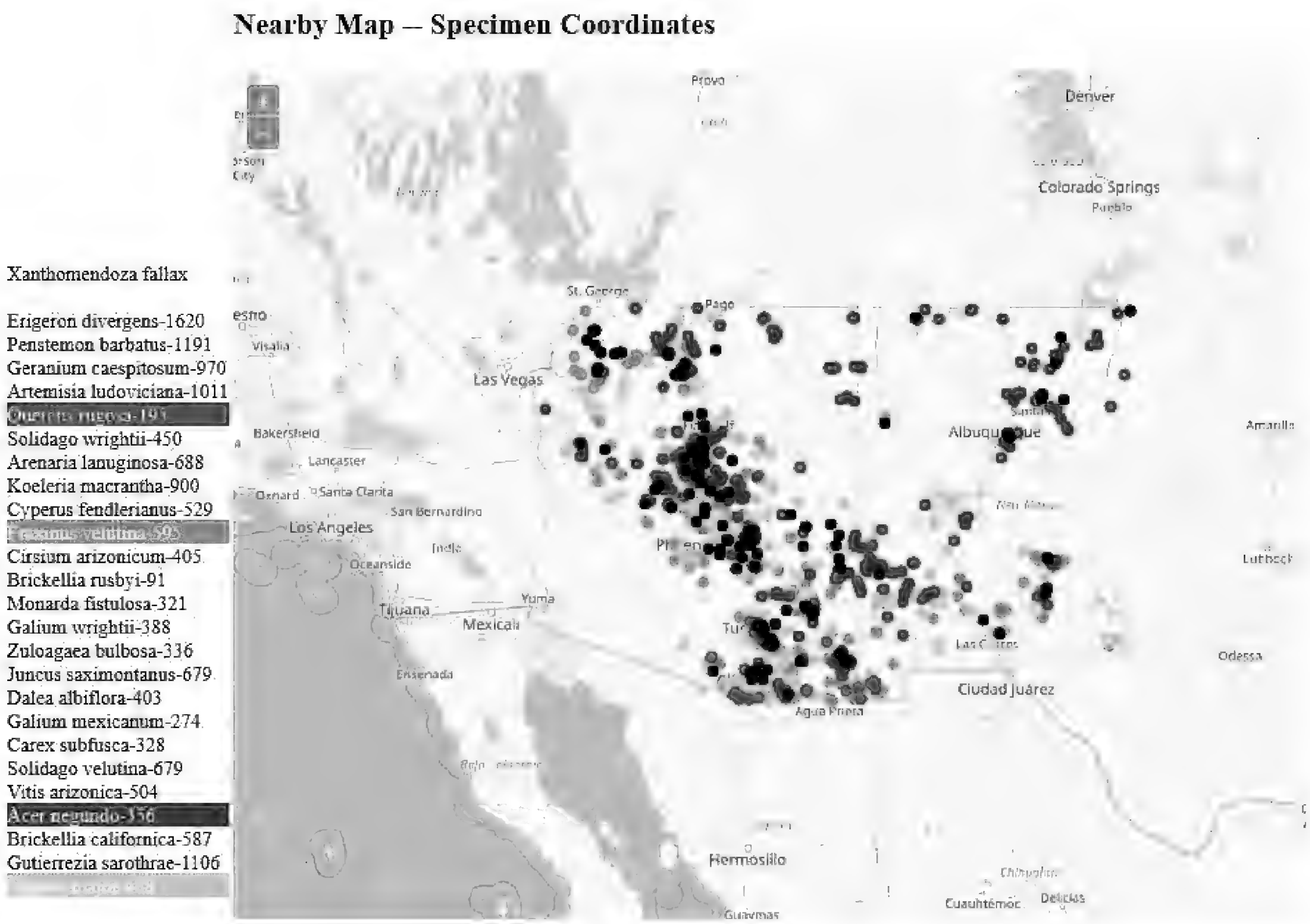


**Figure 8**. Map of lichen *Xanthomendoza fallax* as the Primary species using CNALH. Secondary species of vascular plants are drawn from SEINet. Black dots indicate sites for *X. fallax*, with four tree species indicated by colored dots. See text for explanation.

## CONCLUSION

We believe that NEARBY offers a useful way to explore specimen databases for research and teaching. Perhaps the most broadly useful aspect will be making checklists of Secondary species commonly growing near one or a few Primary species. This should be a

useful tool for anyone exploring a particular kind of vegetation, especially before or soon after fieldwork. Comparing the checklists of different species in one general area, or the same species in different areas should be useful in phytosociological studies. The maps will be useful in discovering patterns of distribution, even in areas where the investigator has never been. We remind anyone using NEARBY that it is not a substitute for fieldwork nor in-depth studies of particular taxonomic groups or kinds of vegetation. We hope it will be used mainly as a tool for preparing for fieldwork and developing hypotheses for further investigation.

Biotic communities, including all organisms, are largely influenced by the plants that live in them. Plants, along with photosynthetic algae and bacteria, are the primary producers. Plants are often large and easily visible, so that when we describe a community of organisms, plants are often the principle entities mentioned. If databases of other organisms such as insects, birds, and fungi, are eventually added to NEARBY, we will be able to discover communities, not only of plants, but of a variety of organisms.

Databases are a good example of the power of working collectively. The larger the databases, and the broader their geographic and taxonomic coverage, the more useful they are. We hope that this program works as an incentive for additional collections to join the databases we have used here and for other databases to become part of NEARBY.

## Acknowledgments

This study would not have been possible without the three specimen databases we have used: SEINet plant database, NEOTROPICAL plant database, and CNALH database of the Consortium of North American Lichen Herbaria. Edward Gilbert facilitated access to the first two, and Frank Bungartz access to the third. Frank also offered valuable advice about lichen species to investigate. Work on this project was hosted at the Arizona State University herbarium where DLL is an adjunct professor and LRL is Curator Emeritus. Various NSF grants have supported the development of these databases and thousands of collectors have contributed millions of specimens. We are grateful to all. Sue Carnahan, Liz Makings, and Frank Bungartz read early versions of this manuscript and offered many helpful suggestions.

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## Appendix A: Program Operation.

**Primary Search**. The MySQL query for the Primary species returns *latitude*, *longitude*, *elevation, collector, collection number,* and *catalog number*. The search includes all subspecies and varieties by appending the MySQL wildcard "%" to the *sciname* parameter but only uses the species binomial. Synonyms are not included unless entered by the user at the beginning of the program.

The search is limited to the geographic area (e.g., states, countries, whole world) selected by the user. It should be kept in mind that the databases mainly include specimens from the Western hemisphere and NEARBY should be restricted to searches in the Americas. If more Primary specimens are found than the user-defined limit, the list of Primary specimens is randomized before the next steps. This is to prevent systematic error resulting from the order in which the specimens were entered into the database.

**Primary with Companion Search**. If a Companion species has been entered, the next step is to query the database for any instances of a Companion specimen within the specified limit of (i.e., nearby) any Primary species specimen. The program iterates through each Primary species specimen one at a time, defining the square around the specimen and finding any Companion specimen within that square. If a Primary species specimen does not have a Companion species within the limit, that Primary species specimen is removed from the list. Note again, this only applies if a Companion species has been entered on the initial page of NEARBY.

The advantage of including a Companion species is that one can better define an environment—in particular, if the Primary species has a broad range. For example, if *Larrea tridentata* were used as the Primary, limiting the search with *Olneya tesota* as the Companion would focus on a more specific vegetation type, i.e., a subtype of Sonoran Desert vegetation.

**Discovering Secondary Species**. The next step is to iterate through each Primary species specimen and find all the other specimens within the defined limit of that Primary species specimen. All of these Secondary species specimens are collated and counted, creating a list

of all Secondary species found near any Primary species specimens. Secondary synonyms are not combined, but all subspecies and varieties are united with the binomial. If a limit on Primary specimens is set, this is where that limit is enforced. Once the program has found Secondary specimens for the limit number of Primary specimens, the iteration stops and the program continues to the next stage. Note that if the list of "usable" Primaries exceeds the limit parameter, they would have been randomized, so that repeated runs with exactly the same setting might yield slightly different results.

**Sorting and Counting**. Next the list of Secondary specimens is sorted by descending number of Primary specimens found near each Secondary species. Then only the Secondary species with the greatest number are retained, based on the number at **"Truncate list of Secondary species at."** The default is 50.

Finally, another query is made of the database to find the total number of georeferenced specimens of the most common Secondary species found in the defined region (e.g., state or country, or worldwide). This number is used to determine what percent of Secondary specimens grow near a Primary species. The total number of Secondaries found nearby is often just an indication of how often it was collected, but by then dividing it by the total number found in the entire region, we get a good estimate of how frequently that Secondary grows near the Primary species.

**Table 2**. Summary of specimen selection. The process of selecting specimens to be used in a NEARBY search follows 7 steps that are summarized here.

1. A search is made for all georeferenced Primary species occurrences in the defined geographic area with coordinate data. If multiple specimens have identical coordinates, only one is used.
2. The upper limit of Primary specimens to be used is the "**Limit**." The default **Limit** is 1000 but another number may be used. If the number of specimens found exceeds the **Limit,** they are randomized.
3. If a Primary species specimen has no specimens of any other species nearby, it is eliminated.
4. If the option "**Don't allow Primary specimens near other Primary specimens**" is selected (the default is to select it), and any two Primary specimens are close enough to be considered Secondaries of each other, only one is used.
5. If a **Companion** species has been selected, only Primary specimens with Companion specimens close enough to be considered Secondary specimens are used.
6. "**Cull specimens if more than**." The **Cull number** is a way of avoiding the use of specimens georeferenced mechanically to a common point, such as the middle of a town. The **Cull number** is set by the user, or the default (50) is accepted. In that case, if in a search for specimens, 50 or more specimens have exactly the same coordinates, they are eliminated. This applies to Secondaries alone and to each Primary and all its Secondaries counted together. Note that locations with more than 100 identically georeferenced specimens are always omitted from all searches, since these locations have almost certainly been programmatically georeferenced to a common point. Therefore, setting this number higher than 100 is the same as setting it to 100. By automatically eliminating these specimens we avoid known situations where hundreds, thousands or tens of thousands of specimens have exactly the same coordinates, which can cause the program to stall as it tries to analyze all the nearby relationships and will give meaningless results.
7. If after the above steps, the "**Limit**" is a number smaller than the remaining number of Primary specimens available, the randomized Primary specimens are reduced to the "**Limit**" number.

Appendix B: Alphabetical list of species names that appear in this paper.

| Scientific Name | Scientific Name Authorship | Family |
|---|---|---|
| *Acer negundo* | L. | ACERACEAE |
| *Acer rubrum* | L. | ACERACEAE |
| *Ageratina herbacea* | (A. Gray) R. M. King & H. Rob. | ASTERACEAE |
| *Amelanchier utahensis* | Koehne | ROSACEAE |
| *Arctostaphylos pringlei* | Parry | ERICACEAE |
| *Arctostaphylos pungens* | H.B.K. | ERICACEAE |
| *Arcytophyllum nitidum* | (H.B.K.) Schltdl. | RUBIACEAE |
| *Arenaria lanuginosa* | (Michx.) Rohrb. | CARYOPHYLLACEAE |
| *Aristida purpurea* | Nutt. | POACEAE |
| *Artemisia ludoviciana* | Nutt. | ASTERACEAE |
| *Asclepias asperula* | (Decne.) Woodson | APOCYNACEAE |
| *Astragalus tephrodes* | A. Gray | FABACEAE |
| *Baccharis tricuneata* | (L. fil.) Pers. | ASTERACEAE |
| *Boechera perennans* | (S. Watson) W. A. Weber | BRASSICACEAE |
| *Bouteloua curtipendula* | (Michx.) Torr. | POACEAE |
| *Brachyotum ledifolium* | (Desr.) Triana | MELASTOMATACEAE |
| *Brachyotum lindenii* | Cogn. | MELASTOMATACEAE |
| *Brickellia californica* | (Torr. & A. Gray) A. Gray | ASTERACEAE |
| *Brickellia rusbyi* | A. Gray | ASTERACEAE |
| *Bromus tectorum* | L. | POACEAE |
| *Bucquetia glutinosa* | (L. fil.) DC. | MELASTOMATACEAE |
| *Calamagrostis intermedia* | Steud. | POACEAE |
| *Carex subfusca* | W. Boott | CYPERACEAE |
| *Castanea dentata* | (Marshall) Borkh. | FAGACEAE |
| *Castilleja fissifolia* | L. fil. | OROBANCHACEAE |
| *Castratella piloselloides* | (Bonpl.) Naud. | MELASTOMATACEAE |
| *Cavendishia bracteata* | (Ruiz & Pav. ex J.St.Hil.) Hoerold | ERICACEAE |
| *Ceanothus fendleri* | A. Gray | RHAMNACEAE |
| *Ceanothus greggii* | A. Gray | RHAMNACEAE |
| *Ceanothus integerrimus* | Hook. & Arn. | RHAMNACEAE |
| *Ceratostema alatum* | (Hoerold) Sleumer | ERICACEAE |
| *Cercocarpus montanus* | Raf. | ROSACEAE |
| *Cirsium arizonicum* | (A. Gray) Petr. | ASTERACEAE |
| *Claytonia perfoliata* | Donn ex Willd. | MONTIACEAE |
| *Comandra umbellata* | (L.) Nutt. | SANTALACEAE |
| *Corydalis aurea* | Willd. | PAPAVERACEAE |
| *Cyperus fendlerianus* | Boeckeler | CYPERACEAE |
| *Dalea albiflora* | A. Gray | FABACEAE |
| *Descurainia pinnata* | (Walter) Britton | BRASSICACEAE |
| *Dichelostemma capitatum* | (Benth.) Alph. Wood | ASPARAGACEAE |

| | | |
|---|---|---|
| *Disterigma empetrifolium* | (H.B.K.) Niedenzu ex Drude | ERICACEAE |
| *Elymus elymoides* | (Raf.) Swezey | POACEAE |
| *Eragrostis curvula* | (Schrad.) Nees | POACEAE |
| *Erigeron divergens* | Torr. & A. Gray | ASTERACEAE |
| *Eriodictyon angustifolium* | Nutt. | BORAGINACEAE |
| *Eriogonum wrightii* | Torr. ex Benth. | POLYGONACEAE |
| *Eryngium humile* | Cav. | APIACEAE |
| *Erysimum capitatum* | (Douglas ex Hook.) Greene | BRASSICACEAE |
| *Escallonia myrtilloides* | L. fil. | ESCALLONIACEAE |
| *Fendlera rupicola* | A. Gray | HYDRANGEACEAE |
| *Fraxinus velutina* | Torr. | OLEACEAE |
| *Gaiadendron punctatum* | G.Don | LORANTHACEAE |
| *Galium aparine* | L. | RUBIACEAE |
| *Galium hypocarpium* | (L.) Endl. ex Griseb. | RUBIACEAE |
| *Galium mexicanum* | H.B.K. | RUBIACEAE |
| *Galium wrightii* | A. Gray | RUBIACEAE |
| *Gamochaeta americana* | (Mill.) Wedd. | ASTERACEAE |
| *Garrya flavescens* | S. Wats. | GARRYACEAE |
| *Garrya wrightii* | Torr. | GARRYACEAE |
| *Gaultheria anastomosans* | (Mutis ex L.f.) H.B.K. | ERICACEAE |
| *Gaultheria erecta* | Vent. | ERICACEAE |
| *Gaultheria procumbens* | L. | ERICACEAE |
| *Gaylussacia baccata* | (Wangenh.) K. Koch | ERICACEAE |
| *Geranium caespitosum* | James | GERANIACEAE |
| *Gutierrezia sarothrae* | (Pursh) Britton & Rusby | ASTERACEAE |
| *Hamamelis virginiana* | L. | HAMAMELIDACEAE |
| *Heliomeris multiflora* | Nutt. | ASTERACEAE |
| *Hesperomeles obtusifolia* | (Pers.) Lindl. | ROSACEAE |
| *Hymenopappus filifolius* | Hook. | ASTERACEAE |
| *Hypericum laricifolium* | Juss. | HYPERICACEAE |
| *Juglans major* | (Torr.) Heller | JUGLANDACEAE |
| *Juncus saximontanus* | A. Nels. | JUNCACEAE |
| *Juniperus deppeana* | Steud. | CUPRESSACEAE |
| *Kalmia latifolia* | L. | ERICACEAE |
| *Koeleria macrantha* | (Ledeb.) Schult. | POACEAE |
| *Lappula occidentalis* | (S. Wats.) Greene | BORAGINACEAE |
| *Larrea tridentata* | (Sessé & Moc. ex DC.) Coville | ZYGOPHYLLACEAE |
| *Lotus humistratus* | Greene | FABACEAE |
| *Lotus wrightii* | (A. Gray) Greene | FABACEAE |
| *Lupinus concinnus* | J. G. Agardh | FABACEAE |
| *Lupinus palmeri* | S. Watson | FABACEAE |
| *Lycopodium clavatum* | L. | LYCOPODIACEAE |

| | | |
|---|---|---|
| *Lycopodium thyoides* | Humb. & Bonpl. Ex Wild. | LYCOPODIACEAE |
| *Macleania rupestris* | (H.B.K.) A. C. Sm. | ERICACEAE |
| *Menodora scabra* | A. Gray | OLEACEAE |
| *Miconia latifolia* | Naudin | MELASTOMATACEAE |
| *Miconia salicifolia* | Naudin | MELASTOMATACEAE |
| *Mirabilis coccinea* | (Torr.) Benth. & Hook. f. | NYCTAGINACEAE |
| *Monarda fistulosa* | L. | LAMIACEAE |
| *Monnina crassifolia* | (Bonpl.) Kunth | POLYGALACEAE |
| *Muehlenbeckia tamnifolia* | (H.B.K.) Meisn. | POLYGONACEAE |
| *Muhlenbergia emersleyi* | Vasey | POACEAE |
| *Myrcianthes rhopaloides* | (H.B.K.) McVaugh | MYRTACEAE |
| *Myrsine andina* | (Mez) Pipoly | PRIMULACEAE |
| *Myrsine dependens* | (Ruiz & Pav.) Spreng. | PRIMULACEAE |
| *Nertera granadensis* | (L. fil.) Druce | RUBIACEAE |
| *Olneya tesota* | A. Gray | FABACEAE |
| *Oritrophium peruvianum* | Cuatrec. | ASTERACEAE |
| *Orthrosanthus chimboracensis* | (Kunth) Baker | IRIDACEAE |
| *Packera neomexicana* | (A. Gray) W.A. Weber & A. Löve | ASTERACEAE |
| *Penstemon barbatus* | (Cav.) Roth | PLANTAGINACEAE |
| *Penstemon linarioides* | A. Gray | PLANTAGINACEAE |
| *Penstemon pseudospectabilis* | M.E. Jones | PLANTAGINACEAE |
| *Pentacalia andicola* | (Turcz.) Cuatrec. | ASTERACEAE |
| *Pentacalia vaccinioides* | (H.B.K.) Cuatrec. | ASTERACEAE |
| *Pernettya prostrata* | Sleumer | ERICACEAE |
| *Pinus edulis* | Engelm. | PINACEAE |
| *Pinus ponderosa* | P. Lawson & C. Lawson | PINACEAE |
| *Pinus strobiformis* | Engelm. | PINACEAE |
| *Plantago patagonica* | Jacq. | PLANTAGINACEAE |
| *Poa fendleriana* | (Steud.) Vasey | POACEAE |
| *Prunus serotina* | Ehrh. | ROSACEAE |
| *Pseudotsuga menziesii* | (Mirbel) Franco | PINACEAE |
| *Psoralidium tenuiflorum* | (Pursh) Rydb. | FABACEAE |
| *Ptelea trifoliata* | L. | RUTACEAE |
| *Quercus chrysolepis* | Liebm. | FAGACEAE |
| *Quercus emoryi* | Torr. | FAGACEAE |
| *Quercus gambelii* | Nutt. | FAGACEAE |
| *Quercus grisea* | Liebm. | FAGACEAE |
| *Quercus rugosa* | Née | FAGACEAE |
| *Quercus turbinella* | Greene | FAGACEAE |
| *Rhus aromatica* | Aiton | ANACARDIACEAE |
| *Rhus trilobata* | Nutt. | ANACARDIACEAE |
| *Ribes erectum* | Freire-Fierro | SAXIFRAGACEAE |

| | | |
|---|---|---|
| *Robinia neomexicana* | A. Gray | FABACEAE |
| *Sassafras albidum* | (Nutt.) Nees | LAURACEAE |
| *Solanum brevifolium* | Dunal | SOLANACEAE |
| *Solanum stenophyllum* | Dunal | SOLANACEAE |
| *Solidago velutina* | DC. | ASTERACEAE |
| *Solidago wrightii* | A. Gray | ASTERACEAE |
| *Symphoricarpus rotundifolius* | A. Gray | CAPRIFOLIACEAE |
| *Tristerix longebracteatus* | (Desr.) Barlow & Wiens | LORANTHACEAE |
| *Tsuga canadensis* | (L.) Carrière | PINACEAE |
| *Vaccinium corymbosum* | L. | ERICACEAE |
| *Vaccinium floribundum* | H.B.K. | ERICACEAE |
| *Vaccinium stamineum* | L. | ERICACEAE |
| *Valeriana microphylla* | H.B.K. | CAPRIFOLIACEAE |
| *Vallea stipularis* | L. fil. | ELAEOCARPACEAE |
| *Viburnum acerifolium* | L. | ADOXACEAE |
| *Vitis arizonica* | Engelm. | VITACEAE |
| *Weinmannia mariquitae* | Szyzyl. | CUNONIACEAE |
| *Xanthomendoza fallax* | (Arnold) Søchting | TELOSCHISTACEAE |
| *Yucca baccata* | Torr. | ASPARAGACEAE |
| *Zuloagaea bulbosa* | (H.B.K.) Bess | POACEAE |

# SOLANACEAE Part Seven:
# *BROWALLIA* L., *CALIBRACHOA* CERV., *CAPSICUM* L., *JALTOMATA* SCHLTDL., AND *SALPICHROA* MIERS

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This paper completes the treatment of Solanaceae for the Vascular Plants of Arizona. All contributions can be found at https://canotia.org/vpa_project.php. A key to the genera appears in Solanaceae Part Two. The only change in the key that is required is incorporating *Margaranthus* into *Physalis*. *Margaranthus solanaceus* Schltdl. is now recognized as *Physalis solanacea* (Schltdl.) Axelius.

## ***Browallia*** L. **Bush-violet**

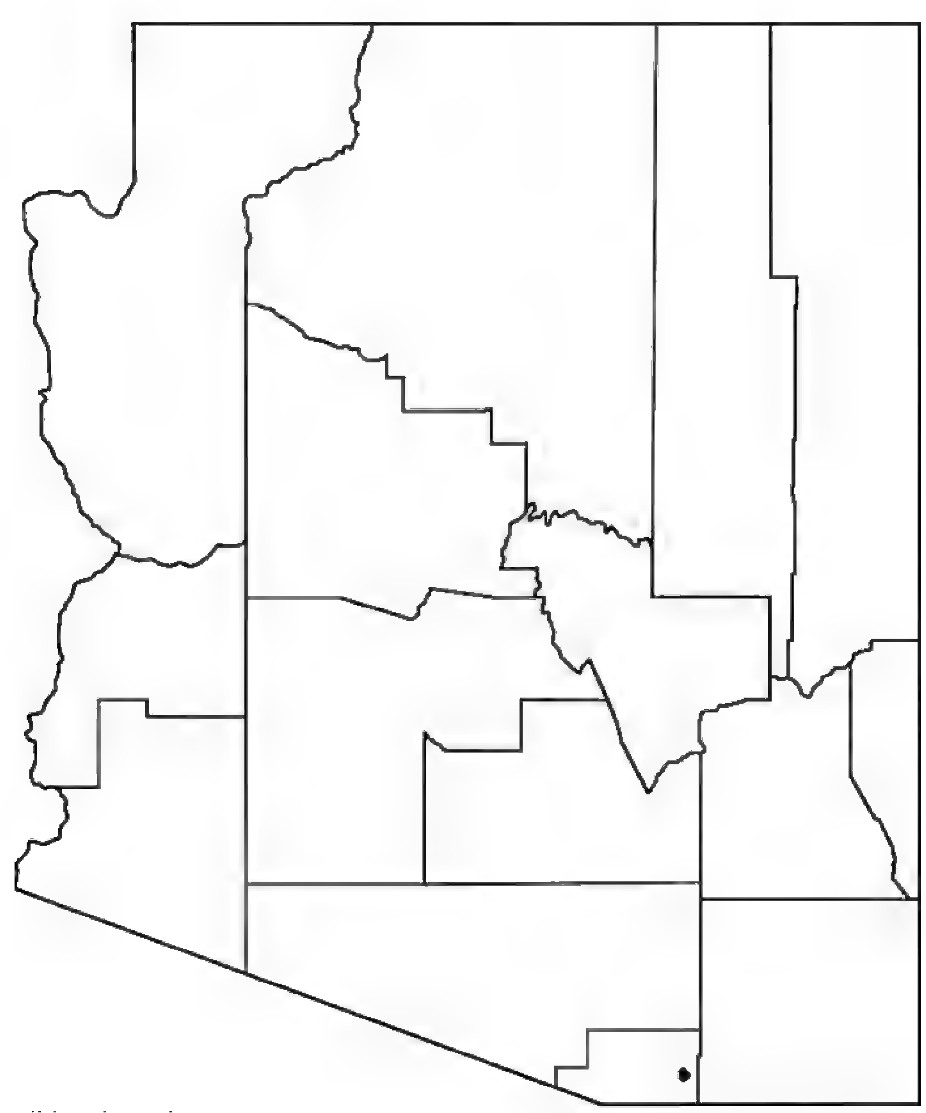
Courtney M. Currier and Elizabeth Makings

Herbaceous annuals, with glabrous to pubescent surfaces. LEAVES simple, subsessile in ours (elsewhere sometimes petiolate), alternate, lanceolate to rhombic or ovate, glabrous, the margins entire. INFLORESCENCES uniflorous. FLOWERS solitary, axillary, perfect, pedicellate; calyx deeply lobed; corolla salverform, zygomorphic, white to yellow in ours (elsewhere white to blue or purple); stamens 4, of two distinct kinds, the upper pair with flattened, curved, pilose filaments, bearing one abortive and one fertile theca, the lower pair with S-shaped filaments, smaller, with two fertile thecae. FRUITS 2-valved capsules, included within calyx; seeds many. —Ca. 22 spp. worldwide with center of diversity in northern S. Amer. (Colombia, Ecuador, and Peru) (named for J. Browallius, Finnish and Swedish theologian, botanist, and physicist, by his friend C. Linnaeus).

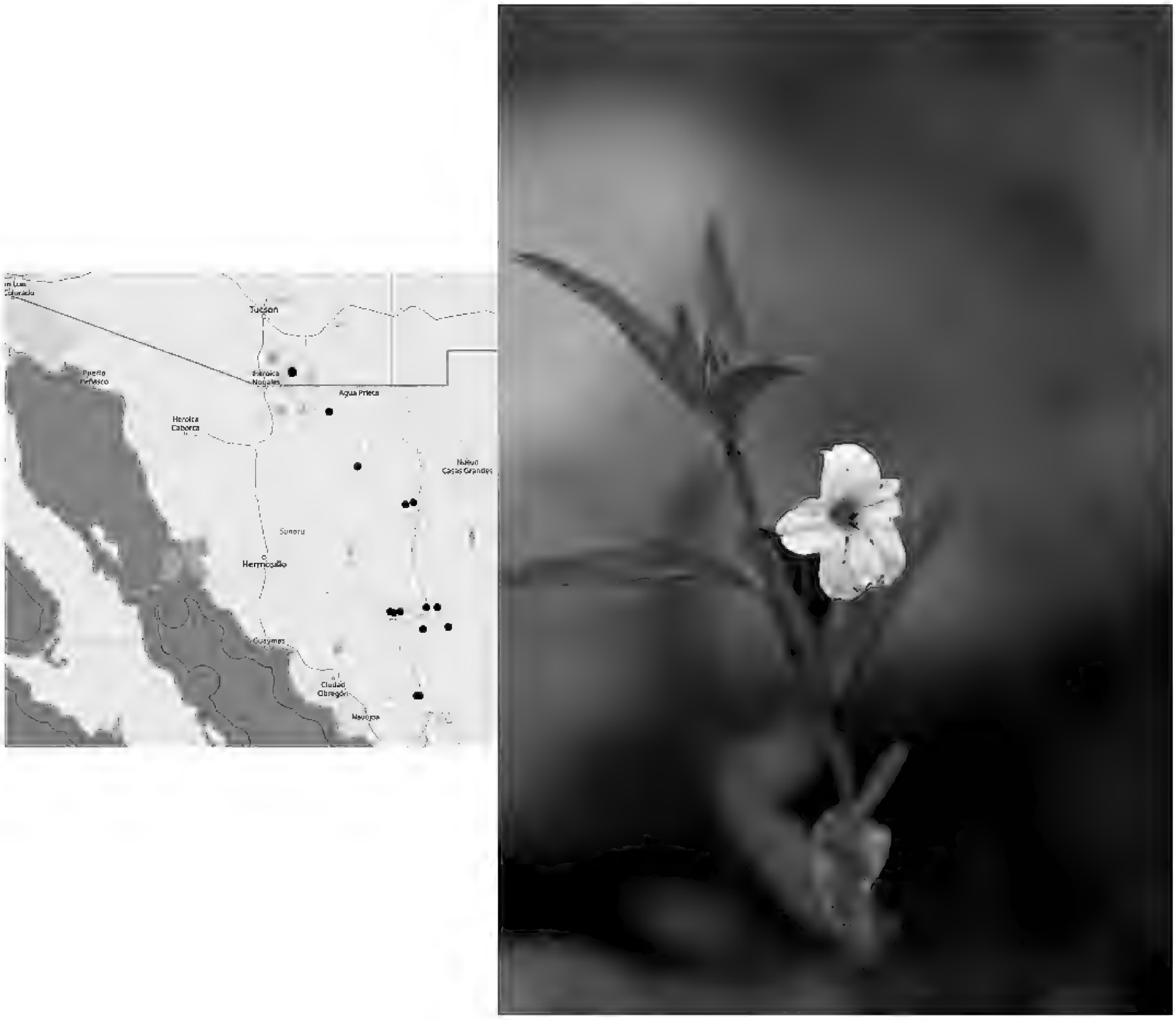
Vascular Plants of Arizona: Solanaceae Part Seven: *Browallia* L., *Calibrachoa* Cerv., *Capsicum* L., *Jaltomata* Schltdl., and *Salpichroa* Miers. *CANOTIA* 17:46–60. 2021.  Published online: 15 Oct 2021

***Browallia eludens*** R. Van Devender & P. D. Jenkins (of ephemeral or elusive nature). —Herbs, typically unbranched, to 20 cm tall, the surfaces glabrous to minutely pubescent, the hairs multicellular and sometimes glandular. LEAVES subsessile, entire, narrowly lanceolate, to 3 cm long, 2–6 mm wide, the margins with glandular trichomes. FLOWERS: pedicels 7–15 mm long; calyces accrescent, not inflated in fruit, about one-half length of corolla; calyx in flower 11–15(–17) mm long, 2–5 mm wide, in fruit 7–11 mm long, 5–6 mm wide, the lobes acute; corolla slightly reflexed, 17–22 mm long, 5–8(–11) mm wide, whitish to pale yellow, the tube exserted beyond the calyx; upper anthers ca. 4 mm long, lower anthers ca. 2 mm long; pistil ca. 12 mm long; ovary glabrous, green; style S-shaped, narrow proximally, wider and convoluted distally; stigma two-lobed, flattened. FRUITS globose, ca. 5 mm long (Van Devender & Jenkins 1993). —Rare in wooded canyons, seasonally riparian or mesic areas; Santa Cruz Co.; 1400–2100 m (4600–6900 ft); Aug; Chih. and Son., Mex.; endemic to s AZ, n Son., and w Chih., Mex. In all spp. of *Browallia*, upper anthers curve downward, thus elevating the dense, multicellular hairs and effectively closing the very small mouth of the corolla (D'Arcy 1973). Figs. 1–3.

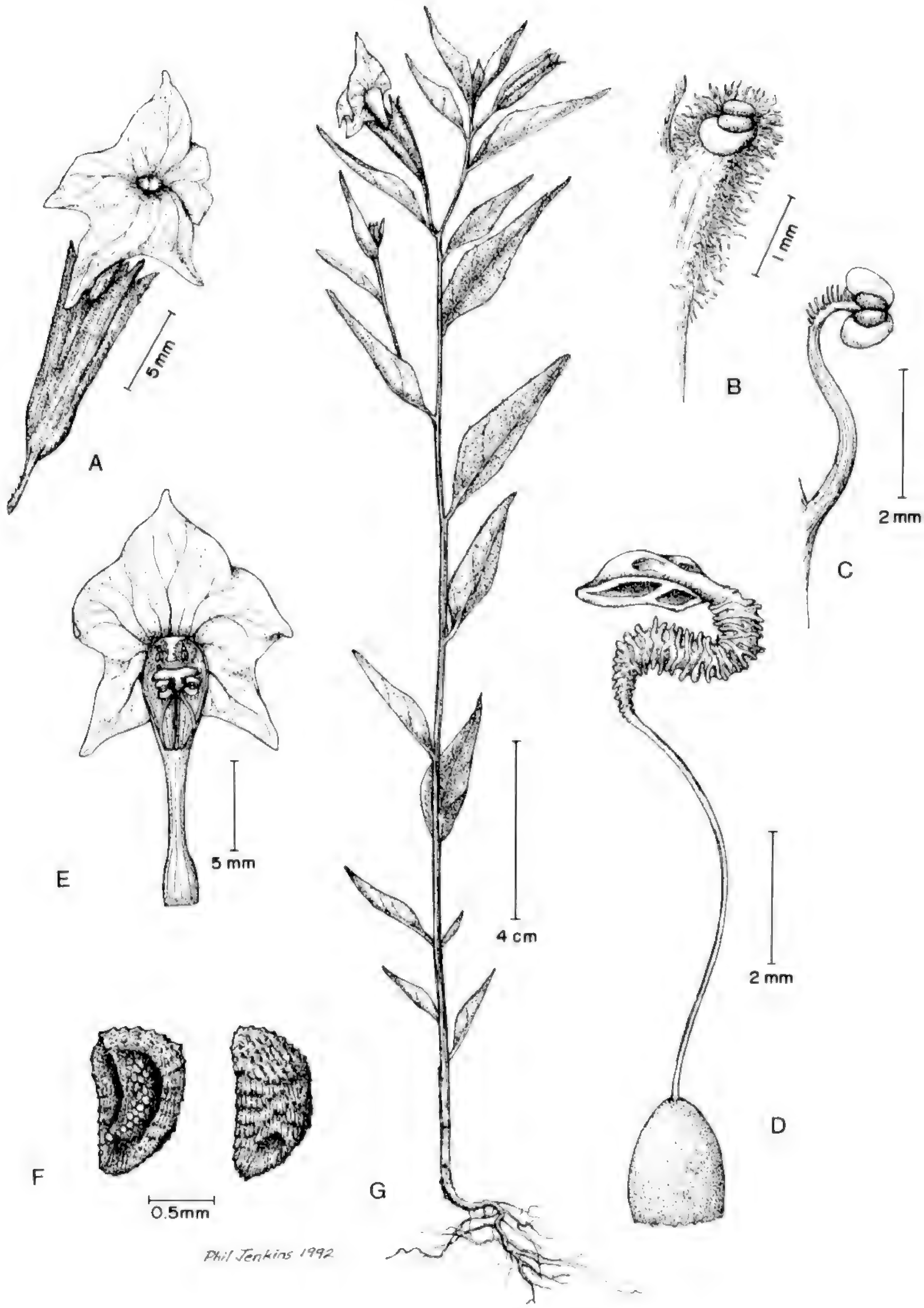
*Browallia eludens* is distinguished from other spp. of *Browallia* by its unbranched habit, sessile leaves, relatively smaller calyx, and well-exserted corolla tube. The corolla is declined obliquely to the tube, creating a unique appearance compared to other spp. The flowers of *B. eludens* are white, whereas blue to violet are more common in other spp. Seeds of *B. eludens* are specifically characterized by their prominent keel, whereas others in the genus are more prismatic in appearance (Van Devender & Jenkins, 1993).



**Solanaceae part 7.** Figure 1. Distribution of *Browallia eludens* in AZ.




**Solanaceae part 7.** Figure 2. Left: Distribution of *Browallia eludens* in AZ and n Mex. Right: Photo by E. Makings taken in Sierra Juriquipa, Son., Mex., Aug 2017.




**Solanaceae part 7.** Figure 3. *Browallia eludens*. A, flower. B, upper stamen. C, lower stamen. D, ovary, style and stigma. E, top view of flower with section of corolla removed to show position of stamens and stigma. F, seed: ventral surface with keel and hilum (left); dorsal surface (right). G, entire plant. Illustration by Phil Jenkins; reproduced from *Madroño* with permission of the editor.

## **Calibrachoa** Cerv. Trailing Petunia

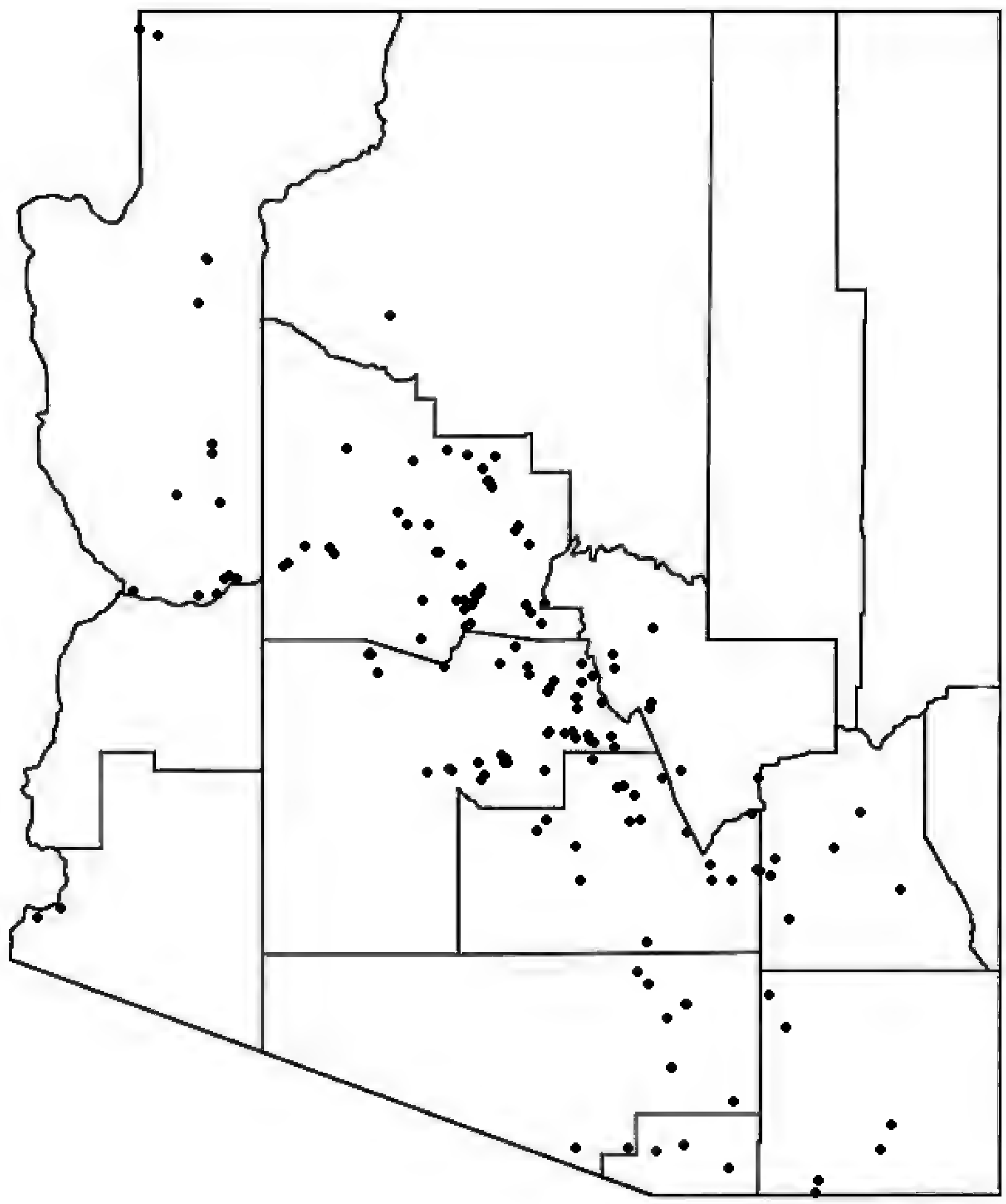
John Anderson and Elizabeth Makings

Annuals to small shrubs, glabrous to glandular-pubescent; stems erect to prostate. LEAVES simple, sessile, often borne in fascicles, linear to lanceolate, entire. INFLORESCENCES solitary flowers, axillary, pedunculate. FLOWERS perfect, actinomorphic, funnelform to rotate; calyx 5-lobed, the lobes linear to subulate, the apices obtuse to acute; corollas white, yellow, orange, or purple with a pale or yellowish tube; anthers yellow. FRUITS ovoid capsules; seeds many. —Ca. 28 spp., mostly S. Amer. (Argentina, Brazil, Paraguay, and Uruguay), 1 sp. (*Calibrachoa parviflora*) in N. Amer. (for Mexican botanist and apothecary Antonio de la Cal y Bracho (1764–1833).

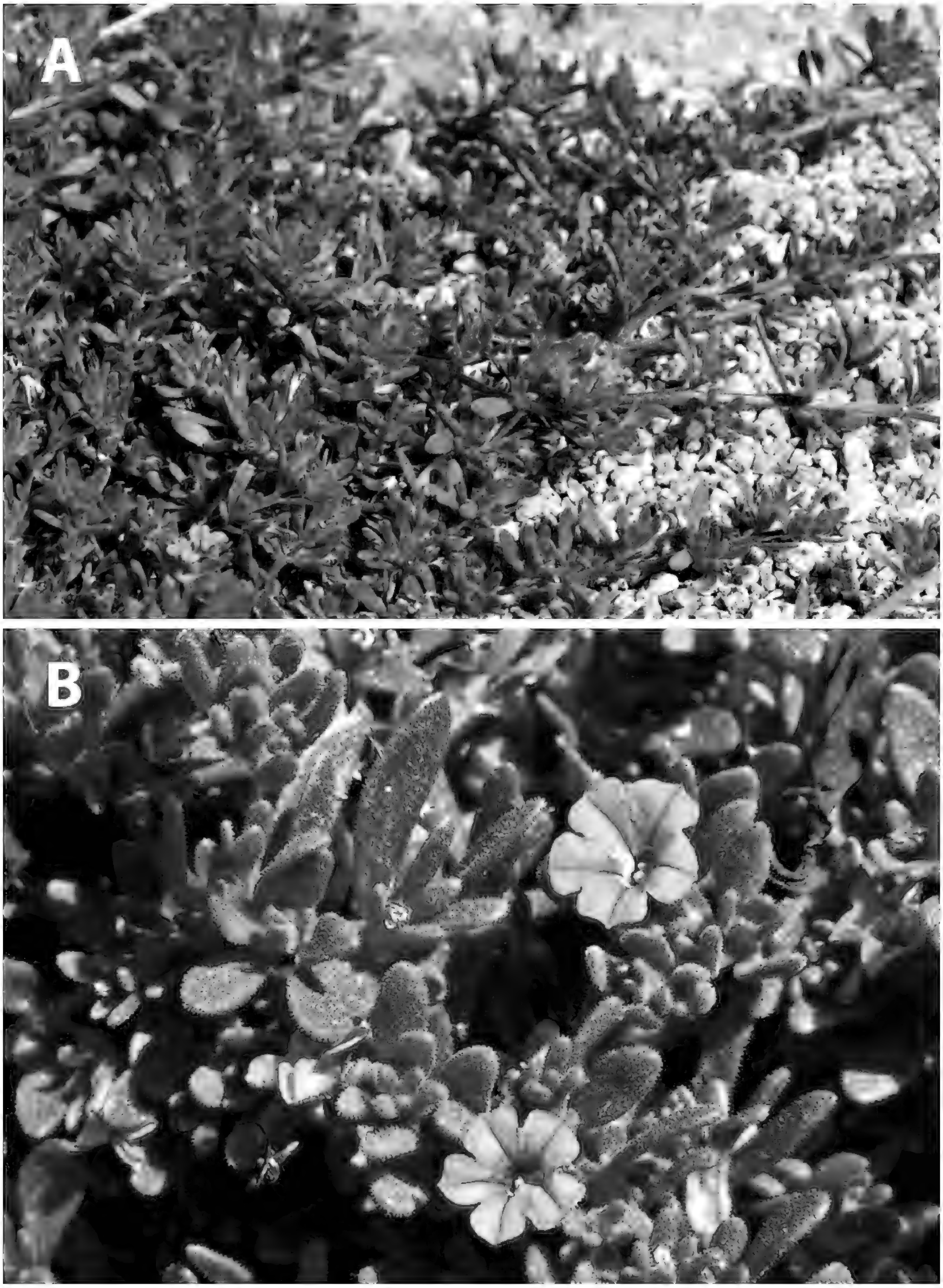
The name *Calibrachoa* was proposed by Cervantes in a book by La Llave and Lexarda (Tropicos.org 2021); the latter botanists are sometimes given credit for the name.

***Calibrachoa parviflora*** (Juss.) D'Arcy (small-flowered). Streamside Petunia, Seaside Petunia. —Annual herbs, rooting along the stem, forming mats, glandular pubescent. LEAVES linear oblanceolate to spatulate, 4–15 mm long; fleshy. INFLORESCENCES: peduncles elongating in fruit 1–10(–15) mm long. FLOWERS 4–7 mm long and wide; calyx lobes 3–6 mm long in flower, increasing to 6–11 mm in fruit; corollas funnelform, purple to violet, with white to yellow tube; stamens five, unequal; filaments epipetalous at base of corolla. FRUITS 3–4 mm wide. SEEDS rounded to blocky, ca. 50 or more. $2n$=18. [*Petunia parviflora* Juss.] —Sandy washes in dry or moist soil in riparian zones: all AZ cos. except Apache, Greenlee, La Paz, and Navajo; 300–1600 m (1000–5200 ft); Apr–Sep; CA to FL, occasional elsewhere in U.S.; Mex.; an amphitropical disjunct also found in S. Amer.; annual habit and self-compatibility may have facilitated long-distance dispersal from S. Amer. Considered naturalized in N. Amer. by Fregonezi et al. (2012); listed in USDA Plants Database (2021) as introduced and as a facultative wetland sp. Figs. 4–5.

*Petunia parviflora* was the first selected type of the genus *Petunia* Juss., which was subsequently divided into two genera: *Petunia* and *Calibrachoa*. To retain the name *Petunia* for the cultivated garden petunias, Wijnands et al. (1986) proposed conserving the generic name, with a new type species, for the $2n$=14 group, which includes the cultivated garden species and hybrids. Their proposal was considered and approved by nomenclature committees and officially accepted by the XIV International Botanical Congress in Berlin, Germany, in 1987. The acceptance of this proposal necessitated the transfer of *Petunia parviflora* to *Calibrachoa parviflora* (Kartesz & D'Arcy 1989; Wijsman 1990).



**Solanaceae part 7.** Figure 4. Distribution of *Calibrachoa parviflora* in AZ.




**Solanaceae part 7.** Figure 5. *Calibrachoa parviflora*. A. Habit (photo by Gene Sturla). B. Close-up of flowers (photo by Neal Kramer, CalPhotos).

**Capsicum** L. Chili Pepper, Bell Pepper

Jonathan Maranville and Elizabeth Makings

Herbaceous annuals to frutescent perennials. STEMS ascending, divergent. INFLORESCENCES with a few or only one flower per node. LEAVES simple, pinnately veined; margins entire to undulate. FLOWERS perfect, actinomorphic, 5-merous; perianth explanate to campanulate; corolla white, yellowish, or violet. FRUITS berries, not enclosed by the calyx, the calyx not inflated in fruit. SEEDS flat and circular. —Ca. 36 spp. Native to the w hemisphere, especially diverse in Mex. and S. Amer., ca. 5 spp. cultivated, some widely distributed in subtropical regions of the world (from Latin *capsa* "case" or Greek *kapto* "to bite").

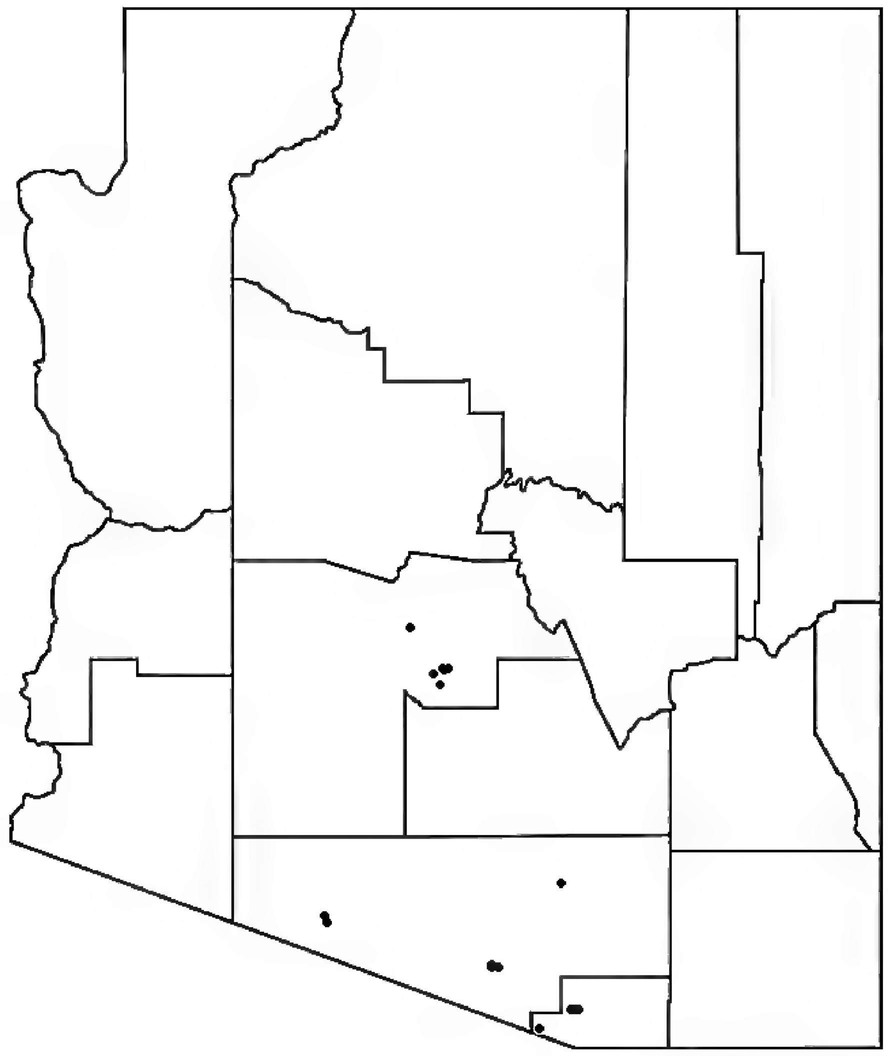
*Capsicum annuum* L., *C. baccatum* L., *C. chinense* Jacq., *C. frutescens* L., and *C. pubescens* Ruiz & Pav. are grown worldwide for culinary and medicinal uses (Heiser and Pickersgill 1969). The fruits have varying concentrations of capsaicin and capsaicinoids, which do not deter birds, but are perceived as localized heat (spicy) by humans and other mammals (Jordt & Julius 2002). Only one species is found wild or volunteering in AZ.

***Capsicum annuum*** L. (for typical annual growth habit). Chiltepin, Chili, Chilli (from Náhuatl *chīlli*). —Annual herb or short-lived perennial. LEAVES 5–35 mm wide; blades 1–6 cm long; petioles 0–16 mm long. FLOWERS nodding, usually only one per node, 3–4 mm wide, the pedicels becoming erect as the fruit matures; filaments white; anthers white, dark blue or dark green, 1–2 mm long; style and stigma white, light green or yellow. FRUITS berries, becoming dry at maturity, indehiscent but easily broken, held erect on pedicels up to 4 cm long; seeds few to numerous, especially rich in spicy heat-mimicing chemicals. —Wild plants widely distributed in subtropical America and perhaps elsewhere; origin of cultivated plants believed to be Mex. (Kraft et al. 2014). Notable cultivars include the bell pepper and various hot peppers. *Capsicum annuum* belongs to a complex of spp. including *C. chinense*, *C. frutescens,* and *C. galapagoense* (González-Pérez et al. 2014). Most authors accept at least a few varieties of the sp. Our wild growing plants belong to a single variety.

***Capsicum annuum*** var**. *glabriusculum*** (Dunal) Heiser & Pickersgill (for smooth, glabrous fruit). Chiltepin, bird pepper. —Up to 2 m tall when growing through and structurally supported by other plants, as in *Makings & Maranville 6466* (ASU). LEAVES ovate or lanceolate; bases cuneate (occasionally hastate); apices acuminate; blades 1–2 cm long. FRUITS globose, 4–7 mm wide. SEEDS from two to ten or more per berry. Canyons, disturbed areas: Maricopa, Pima and Santa Cruz cos.; 300–1,800 m (1,000–6,000 ft); fl. Aug–Sep (fr. Nov–Jan); AZ, CA, FL, LA, TX s to Mex, Caribbean, C. Amer., and S. Amer. Wild specimens have been collected in Arizona in canyons south of 32°10' N in Pima and Santa Cruz counties. One such population, located in the Tumacacori Mountains of the Coronado National Forest in Santa Cruz County, gained protection in 1999 as the Wild Chile Botanical Area. The primary associated spp. at this site are the hackberries, *Celtis pallida* and *C. reticulata*; these woody plants may have co-evolved with this variety of *Capsicum annuum* to produce fruit that is very similar in appearance (Tewksbury et al. 1999). Figs. 6–7.

Two other Arizona populations occur in Pima County: one in the Baboquivari Mountains and one in the Ajo Mountains. An additional population can be found in the vicinity of El Sásabe, Son., Mex., within 5 km of the Arizona border.

Wild-type volunteers have been collected in the Phoenix and Tucson metropolitan areas.



**Solanaceae part 7.** Figure 6. Distribution of *Capsicum annuum* var. *glabriusculum* in AZ. Dots in urban areas of Phoenix and Tucson probably indicate volunteer escapes from cultivation.

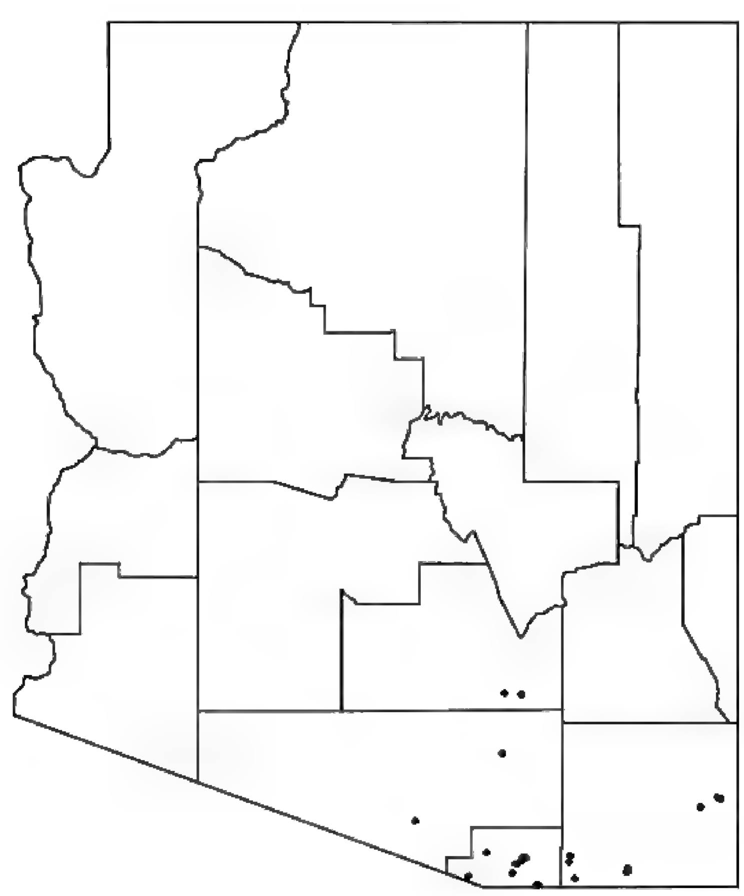
**Solanaceae part 7.** Figure 7. *Capsicum annuum* var. *glabriusculum,* (A) flower (B) fruit (photos by L. R. Landrum).

**Jaltomata** Schlechtendahl False Holly

John Anderson, Kariah Slagel, and Elizabeth Makings

Herbaceous perennials to shrubs, with stems erect to procumbent, glabrous to pubescent. LEAVES simple, petiolate, alternate, ovate to lanceolate, entire or toothed. INFLORESCENCES umbellate, axillary, pedunculate. FLOWERS perfect, actinomorphic, rotate or campanulate; calyx deeply 5-lobed, accrescent (increasing in size) but not enclosing the fruit; corollas pale green, whitish, blue or purple; anthers dehiscing longitudinally. FRUITS globose berries, orange to black. —Ca. 60 spp., 1 sp. in AZ, from se AZ s to W. Ind. and n S. Amer. including the Galapagos Islands (possibly a variant of Jaltomate, the name of a small pueblo in Zacatecas, Mex.; *jaltomata*, a Mexican vernacular name for false holly; Nahuatl: *xalli* for "sand" and *tomatl* for "tomato").

***Jaltomata procumbens*** (Cav.) J. L. Gentry (spreading over the surface of the ground). Creeping False Holly. —Perennial herb from tuberous roots, erect to procumbent, with stems 4–5 angled, to 80 cm high, glabrous, plants poisonous except for mature berries. LEAVES ovate, 8.5 cm wide by 13 cm long, membranous, glabrous; apex acuminate; base cuneate; margins entire to repand; petioles winged, to 4.5 mm long. INFLORESCENCES umbellate, with 6–18 flowers, axillary; peduncle with longitudinal ridges, to 3 cm long. FLOWERS 20–30 mm wide; calyx 9–13 mm wide, green at flowering, at fruiting 18–25 mm wide, purple (partially accrescent); corollas rotate, pale green to whitish; filaments equal, epipetalous at base of corolla, 4.5–7 mm long; anthers yellow, protogynous. FRUITS berries, 18–25 mm in diameter, dark purple to black, edible (gathered and eaten uncooked in Mex.). $2n = 24$. [*Atropa procumbens* Cav., *Saracha procumbens* (Cav.) Ruiz & Pavon, *S. sessilis* Greene]. —Canyon bottoms and hillsides in rich soil under shade of trees and occasionally in oak savannah: Cochise, Pima, Pinal, and Santa Cruz cos.; 1050–1500 m (3500–5000 ft); Jul–Sep; se AZ to n S. Amer. (Mione 2021). Figs. 8–9.



**Solanaceae part 7.** Figure 8. Distribution of *Jaltomata procumbens* in AZ.


**Solanaceae part 7.** Figure 9. *Jaltomata procumbens*. A. Habit. B, C. Flowers. D. Fruit. Photo credits: A. Patrick Alexander; B–C. Sue Carnahan; D. Frank Rose.

## **Salpichroa** Miers

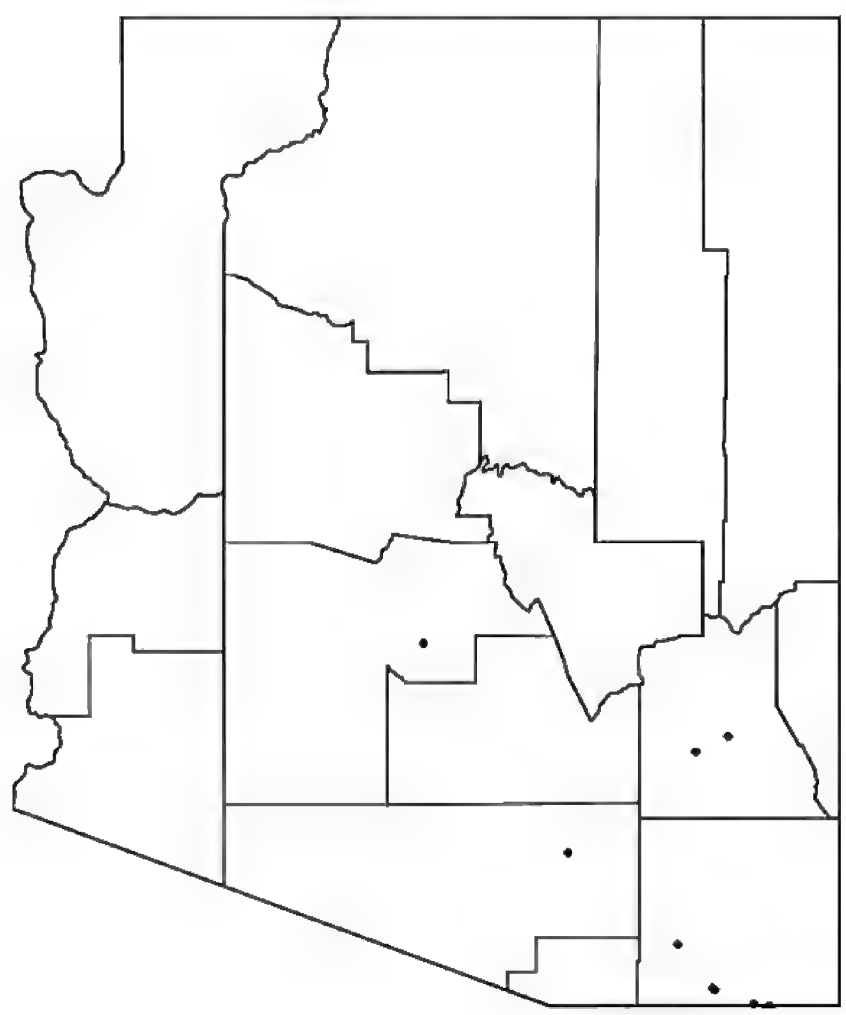
Courtney M. Currier and Elizabeth Makings

Herbaceous perennials, unarmed, the surfaces often pubescent. LEAVES simple, petiolate, alternate and/or opposite, ovate to obovate to rhombic, glabrous to hairy, the margins entire. INFLORESCENCES axillary, uniflorous. FLOWERS 5-merous, actinomorphic, perfect, short-pedicellate, pendent, visited by hummingbirds, moths, and bees; calyx deeply lobed, not inflated in fruit; corolla urceolate in ours (elsewhere sometimes tubular), with lobes rotate to reflexed, creamy white to yellow to yellow-green to reddish orange; stamens 5, equal. FRUITS ovoid berries, white to pale yellow; calyx not inflated in fruit; seeds many. —Ca. 21 spp., 1 in AZ, native to S. Amer. with center of diversity in Peru; our sp. widely naturalized. (Greek: *Salpinx*, “trumpet” and *chroa*, “skin” or “complexion,” referring to flower or corolla).

***Salpichroa origanifolia*** (Lam.) Thell. (leaves like oregano). Cock’s eggs, lily-of-the-valley vine, pampas lily-of-the-valley. —Herbaceous perennial vine or shrub, to 2 m tall, arising from a rhizome. Surfaces pubescent, more densely so on new growth, the hairs multicellular, sometimes uncinate. LEAVES to 3.5 cm long, 1.5–25(–27) mm wide, minutely

glandular; petioles 2–20 mm long. INFLORESCENCES uniflorous. FLOWERS on slender pedicels 4–6(–8) mm long; calyces 2–4 mm long, about one-quarter to one-third length of corolla, the lobes acute; corolla urceolate, with reflexed lobes, 8–10 mm long, 2–5 mm wide, white to creamy yellow; anthers ca. 2 mm long, longitudinally dehiscent, dorsifixed, slightly exserted; pistil pubescent with multicellular hairs, especially at base, the ovary dark red-brown at base, the style slightly exserted. FRUITS globose, ca. 2 mm long. —Uncommon in irrigated environments, canyons, seasonally riparian areas; Cochise, Graham, Maricopa, and Pima cos.; 750–1400 m (2500–4500 ft); Aug–Oct; AL, AZ, CA, CT, FL, GA, LA, MO, NC, SC, TX; BC, Can; Son., Mex.; native to S. Amer.; naturalized in N. Amer., Europe, Africa, Australia, New Zealand. Figs. 10–11.

*Salpichroa origanifolia* is the most widespread sp. of the genus, sometimes considered an ornamental or a weed. Recent research suggests that fruits of *S. origanifolia* may have antimicrobial properties (Díaz et al. 2018). A group of steroids termed "withanolides" naturally occur as secondary compounds in *Salpichroa* and among other genera of the *Solanaceae*. Withanolides isolated from *S. origanifolia* exhibit inhibitory effects on insect pests and other herbivores (Bado et al. 2004); thus, pesticide uses for these compounds are being explored from this plant. *Salpichroa* is related to *Nectouxia*, and merging the genera is being considered. *Nectouxia* is the older name and thus has priority but preserving the name *Salpichroa* through nomenclatural conservation would be possible (Carrizo García et al. 2018).



**Solanaceae part 7.** Figure 10. Distribution of *Salpichroa origanifolia* in AZ.

**Solanaceae part 7.** Figure 11. *Salpichroa origanifolia* in flower (Photo by Elizabeth Makings).

## ACKNOWLEDGMENTS

We thank the curators and staff at the University of Arizona and Arizona State University who made specimens available for study. We also thank Daryl Lafferty for use of the Plant Map programs. Mark Porter provided copies of pertinent literature and assisted with specimen access at Rancho Santa Ana Herbarium. Sue Carnahan and Les Landrum offered many helpful comments on early versions of this manuscript.

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# The Decline and Fall of a Large Saguaro

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I have been going to Usery Mountain, about a 30-minute drive from my home in Tempe, Arizona, ever since in the 1970s when I encountered male tarantula hawk wasps (*Hemipepsis ustulata*) defending their territories on foothill paloverdes (*Parkinsonia microphylla* Torr.) on the ridgeline. A few years later I moved uphill to the highest peak in the mountain system, still less than 4000 feet in elevation. I began to photograph the saguaros (*Carnegiea gigantea* [Engelm.] Britton & Rose) on the north side of the mountain, at which time I noticed that the larger saguaro cacti were prone to collapses that left them dead, while the smaller saguaros grew taller and taller over time. From these smaller saguaros would come the replacements for those that died, provided that the smaller cacti survived a great many years, thanks to an abundance of good luck (no killing frosts, no bacterial infections, and no microburst wind storms).

My first photograph of the largest saguaro on the mountainside was taken in 1990. Even then, after a century or so of growth, I could detect a slight lean of the cactus downhill. Little had changed by 2005 but then in May 2010 (twenty years after my first photograph) the lean was definitely more pronounced (Fig. 1), the effect of being top heavy and shallow rooted in soils that had softened as a result of spring rain. When I checked on the saguaro in the following month I found it broken at its base, sprawled out on the mountainside – moribund (Fig. 2). In my experience no saguaro resprouts from its base after a collapse. Survivors of a fall are apparently nonexistent, although I have seen some upright columnar cacti survive a bad frost or wildfire.

By October of that same year, the green flesh of the saguaro had turned brown and cracked. Six years later, the saguaro was reduced to its internal "ribs," the fleshy material having disappeared completely in the intervening years.

I continued to come to Usery Peak for two years during which time the skeleton of the cactus persisted but in 2019 I began to fall on the trail up the mountainside, a trail that I had constructed with my own feet. My son, a doctor, decreed that I was to give up my ascents and descents, advice that I followed, albeit reluctantly. The fate of older fallen saguaros showed me all too clearly what could happen after a fall, and I was not eager to emulate them.

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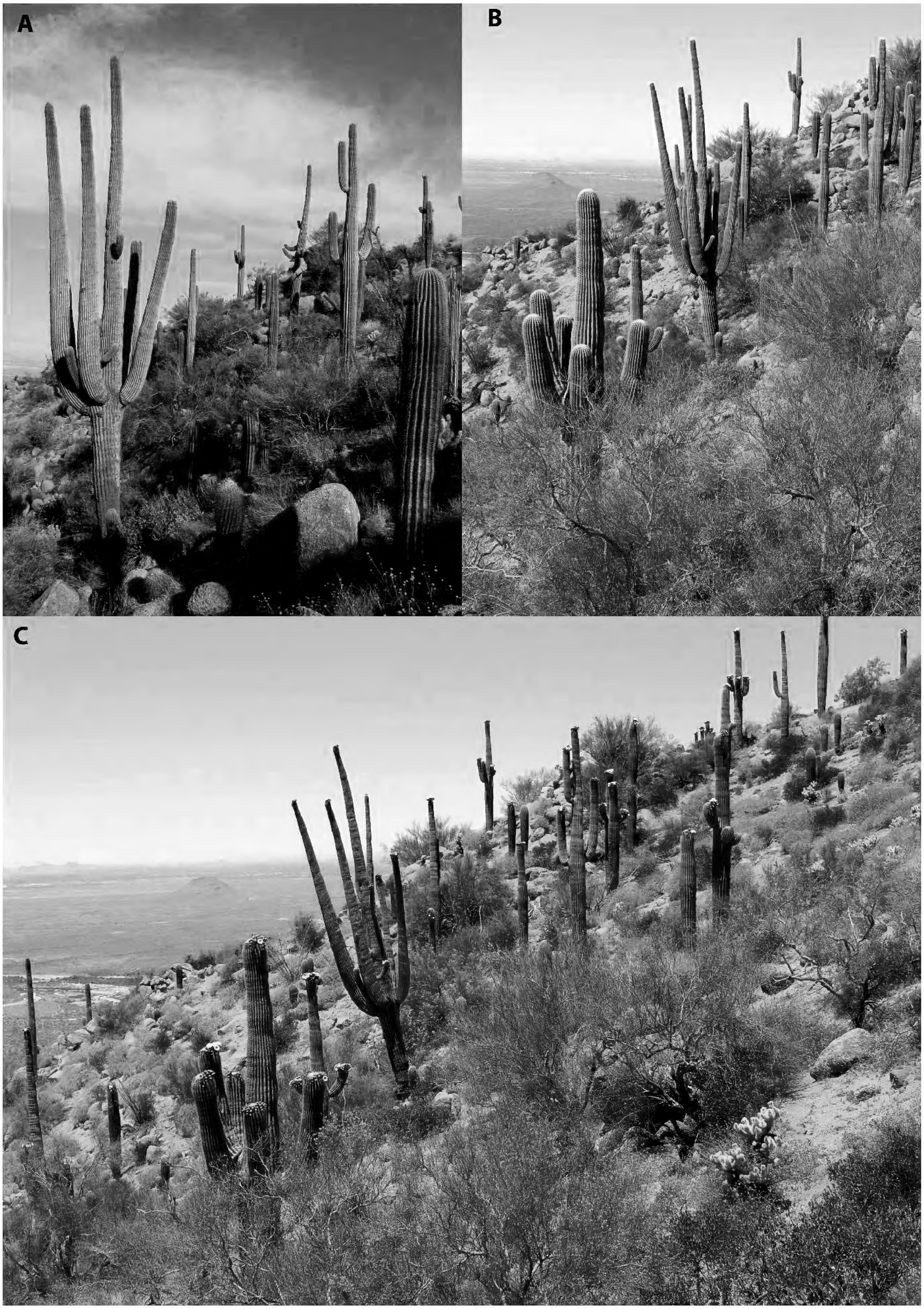


Figure 1. Saguaro before the fall. A, August 2008. B, February 2010. C, May 2010.

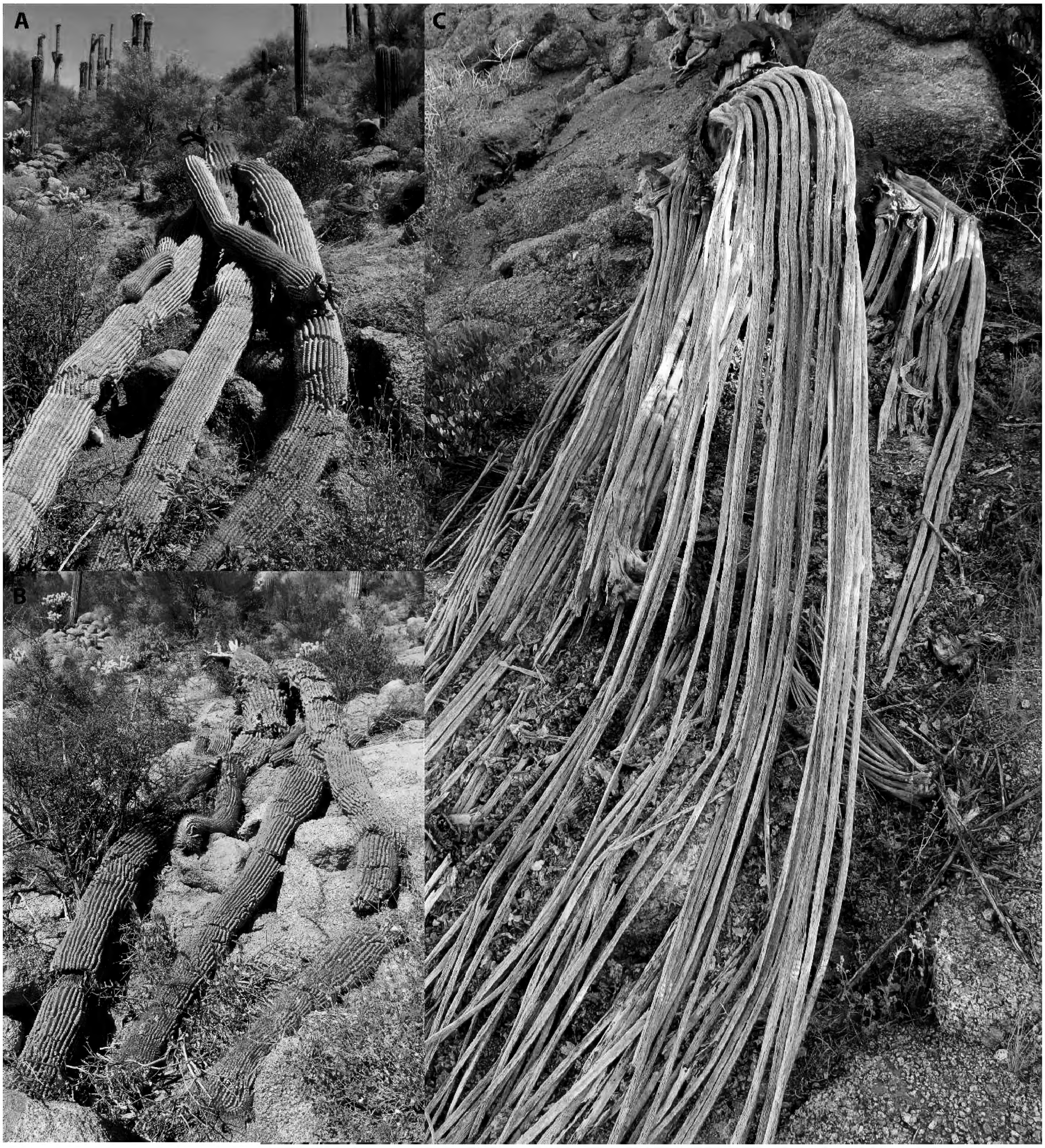


Figure 2. Saguaro after the fall. A, June 2010. B, October 2010. C, June 2016.